Saskatchewan Agriculture, Food and Rural Revitalization

ADF

AGRICULTURE DEVELOPMENT FUND

FINAL REPORT

20000053

AGRONOMIC STUDIES FOR WINTERFAT (EUROTIA LANATA) SEED PRODUCTION, FORAGE HARVEST, AND PLANT MIX REQUIREMENTS

Funded by:
The Agriculture Development Fund

June 2004
Prepared by: University of Saskatchewan

104-05882/

Agronomic Studies for Winterfat Seed Production, Forage Harvest and Plant Mix Requirements

ADF Project Number 20000053
SPARC # A03679-0960-2123

ADF Contact: Dawn Loveday
SPARC Project Leader: M.P. Schellenberg

Final Report: March, 2004

(a) Abstract: The three objectives were **1:** Increase seed yield by manipulating soil N and P and moisture availability; **2:** Determine impact of time of harvesting on ecotypes and potential of additional nutrients to dissipate loss of productivity resulting from incorrect time of utilization; **3:** Provide appropriate plant mix which includes winterfat; address areas requiring further knowledge to increase winterfat utilization.

For 2001 the first sites were established under drier, warmer and windier environmental conditions than the available long term averages. Winterfat established better than alfalfa or western wheatgrass under pressure from weedy species. Providing 2.5 cm water in August and September had a significant impact on soil moisture, which was still detectable at the final measurement in October.

The year 2002 was cooler and wetter than long term averages. This resulted in no benefits from irrigation for seed production. With the above normal precipitation a leaching effect appeared to have occurred with addition of fertilizer having no benefit for any of the studies. The low temperatures were below optimal temperatures for New Mexico seedlings that resulted in no plant development beyond the vegetative state. Ducks Unlimited plants initiated growth earlier and completed their full life cycle. Completion of the life cycle resulted in more fibrous plants with less organic matter content for the Ducks Unlimited plants. New Mexico plants were taller and yielded 35 % more biomass per plant. The new Mexico plants may have better nutritional quality but self-replacement may become an issue. In a seed mix with alfalfa and western wheatgrass, winterfat contributed to the species composition greater amounts. These amounts were closer to the seeded amounts for winterfat than the other two. Weeding benefited all seeded species although winterfat continued to contribute more under weedy conditions than western wheatgrass or alfalfa. Suggesting under field conditions winterfat may have a greater capacity to compete with weeds than alfalfa or western wheatgrass.

For 2003 a hot dry climate was encountered. The climate was more conducive for winterfat growth and seed production for plants originating from the Ducks Unlimited seed source. New Mexico seed source plants suffered a dieback due to the previous year's excessive moisture. The lack of dieback among Ducks Unlimited plants suggests a source of disease resistance for future breeding considerations. Fertilization for seed production required a full year to have an impact. The impact was negative due primarily to delayed flowering resulting in increased numbers of aborted flowers during the hottest portion of the summer. This delay was likely increased with addition of water during the flowering phase. Fertilizer, in the manner it was applied for these studies, failed to provide a benefit. New Mexico plants continued to have more desirable nutritional quality characteristics than Ducks Unlimited plants. Both plant types had distinct mineral compositions which could be potentially manipulated for optimization within a breeding program. Magnesium and iron were two minerals which did accumulate to levels above maximum tolerable levels. For fall grazing crude protein, manganese, potassium and sulfur were sufficient for a replacement Angus heifer in the first trimester. Organic matter digestibility ranged from 55% to 71% for the fall period. Ducks Unlimited plants did not decline with 50% removal of plant height during any clipping date. Winterfat within the seeding mixes declined to levels below a significant nutritional contribution. Methods need to be developed to increase the proportion of winterfat within a seeded plant community. Possible avenues for solution include increasing amount of winterfat seed in the mix and/or selection of less competitive companion species.

Implications for management are: 1) Fertilizer applied in the manner found within these

studies was not beneficial and therefore value is questionable; 2) Fifty per cent removal, by height, did not affect plant production negatively when plants given a full year to recover. Winterfat can be grazed during the year but only for short duration and 50% removal with a full year recovery period; 3) New Mexico and Ducks Unlimited plants had different growth patterns and nutritional profiles. The differing growth and nutritional profiles could be exploited to develop a more optimal forage shrub; 4) The Ducks Unlimited plants, for fall grazing, had adequate crude protein, manganese, potassium and sulfur for a replacement Angus heifer in the first trimester. Magnesium and iron were two minerals which did accumulate to levels above maximum tolerable levels; 5) Species mixes tested were found to fall below desirable levels of winterfat content by the second year indicating the seed mix will require a higher amount of winterfat seed and/or less competitive companion species.

Additional research should include a greater number of winterfat ecotypes to develop a more complete nutritional profile which could lead to breeding for improvement of growth and nutritional characteristics. Also additional sites with differing soil mineral makeup should be utilized to determine mineral accumulation potentials of the winterfat ecotypes.

(b) Executive Summary:

Objective 1: Increase seed yield by manipulating soil N and P and moisture availability.

Of the two plant types used in this study only Ducks Unlimited plants yielded seed. Fertilization required a full year to have an impact. The impact resulted in delayed flowering resulting in decreased seed yield. Seed production benefitted from the hot dry environment encountered in 2003.

Objective 2: Determine impact of time of harvesting on ecotypes and potential of additional nutrients to dissipate loss of productivity resulting from incorrect time of utilization.

Harvesting at 50% of height failed to result in a decline for the two years of harvest for Ducks Unlimited plants. New Mexico plants (seed most commercially available) suffered a dieback in the winter of 2002-2003 due to the excessive moisture in 2002. Both plant types have unique growth patterns and nutritional make ups. Magnesium and iron were two minerals which did accumulate to levels above maximum tolerable levels. For fall grazing crude protein, manganese, potassium and sulfur were sufficient for a replacement Angus heifer in the first trimester. Organic matter digestibility ranged from 55% to 71% for the fall period.

This plant would make a good fit in a late season pasture utilized for grazing. Grazing earlier in the year would be tolerated at 50% of height levels with a full year to recover. All season grazing access would not allow appropriate grazing levels or adequate recovery period.

There exists within the two plant types examined, sufficient differences in disease resistance and nutritional makeup for opportunities to optimize nutritional contributions of the plant through breeding. Plants from other locations should be screened to determine their potential contributions. Also additional research is required to determine soil mineral impact on plant mineral content.

Objective 3: Provide appropriate plant mix which includes winterfat; address areas requiring further knowledge to increase winterfat utilization.

Winterfat seed making up 40% of the seed mix failed to result in an adequate proportional contribution to the established plant mix. The plant mix had sufficient crude protein for a replacement Angus heifer in the first trimester grazing in fall. Organic matter digestibility of the final plant mix was 52%.

(c) Technical Report

(c1) Project Summary

Winterfat is known to maintain high nutritional quality and palatability in the late grazing season when other sources generally are deficient. Agro-economists have identified a substantial savings if cattle are maintained in the pasture as opposed to feed lots. With high fall nutritional value winterfat would contribute to maintaining livestock for longer periods in the pasture. This semi-shrub has generated a great deal of interest among producers as well as environmental groups. SPARC has recently developed an ecovar^{TM} for Ducks Unlimited of winterfat. DU presently has the seed for increase prior to release to the public. But there are a number of agronomic questions which must be addressed if this crop is to reach its full potential in the agricultural industry. Issues which must be addressed impact the seed, forage and livestock industries.

Work is presently underway to address some issues such as seeding, and seed harvest. Other issues still needing to be addressed include consistent seed production, actual impact of season of grazing on winterfat and number of winterfat plants in a required stand. Therefore this project will address these areas with the following three objectives. **Objective 1:** Increase seed yield by manipulating soil N and P and moisture availability. **Objective 2:** Determine impact of time of harvesting on ecotypes and potential of additional nutrients to dissipate loss of productivity resulting from incorrect time of utilization. **Objective 3:** Provide appropriate plant mix which includes winterfat.

These objectives will be achieved using proper statistically designed experiments. The first study will be directed to objective 1 using time of application of fertilizer and water. Effects known to affect seed production in grasses. The second study applies to the second objective and will determine the impact of date of harvest and the potential of increased soil nutrients to alleviate potential adverse effects. The third study will delineate the appropriate quantity of winterfat required in a plant community to provide the desired nutritional quality.

With these objectives being met the seed, forage and livestock industry will have management tools in place which will improve the odds of winterfat reaching its full potential and making a valuable contribution to sustainable agriculture in the Prairie provinces.

(c2) Project Outline

The project addresses three objectives which will provide key information required to manage the seed crop as well as the plant as a forage. As indicated earlier management information for this potential forage is lacking and will be required if both the seed and livestock industry are to obtain full value for this plant. Multiple years will be required to assess agronomic practices. As with most perennials winterfat is highly sensitive to environmental factors and therefore a single years' results may well be misleading.

Objective 1: Increase seed yield by manipulating soil N and P and moisture availability.
It has been noted in present studies that seed production, as with several native species, is strongly affected by a number of environmental influences such as moisture and available

nutrients. Responses to increased moisture and available nitrogen have been noted to increase productivity. In order to determine best agronomic practices for improving year to year seed production a nursery would be established in fall of 2000. A full factorial randomized complete block design would be used. Factors included are: 1) time of N (100 kg/ha) & P (50 kg/ha) annual application - fall or spring, 2) time of water application - Early August or late September. A check plot with no applications is also included. Replications will be 4. Seed yields will be taken as well as plant height, basal and canopy cover. Soil sampling in spring will occur to determine appropriate level of soil nutrients will also occur.

Objective 2: Determine impact of time of harvesting on ecotypes and potential of additional nutrients to dissipate loss of productivity resulting from incorrect time of utilization.
Winterfat is generally considered to be best adapted to late season grazing. The shrub has been noted to exist under continuous grazing systems with livestock camping on winterfat dominated plant communities which indicates tolerance to some grazing outside the desired season as well as some ecotypic adaptation. Information is therefore required to determine the effect to the plant when grazed outside the optimum time, do differing ecotypes have higher grazing tolerances and is there a method to decrease the negative impact. One possibility would be to provide nutrients thereby decreasing energy required to scavenge nutrients in a traditionally low nutrient environment. To meet the objective a study site would be planted in fall 2000. A full factorial randomized complete block design would be used. Factors included are: 1) ecotypes - New Mexico and DU Ecovar^{TM} seed, 2) Fertilized and non-fertilized and 3) six harvest dates (June, July, August, September, October and November). Replicates would be four. Data to be collected would include : 1) above and below ground biomass, 2) nutritional quality and 3) N and P content of soil.

Objective 3: Provide appropriate plant mix which includes winterfat.
One question which is often asked by producers is how much winterfat should one have? At this point in time the only partial answer available is based on historical records which indicates too much winterfat results in overly fat cattle. To address this question plots will be seeded in spring 2001 and 2002. The plots would be arranged in a randomized complete block design with 4 replicates. Treatments would be four seed mixes: 1) 5%winterfat, 20% alfalfa, 75% western wheatgrass; 2) 10%winterfat, 40% alfalfa, 50% western wheatgrass; 3) 20%winterfat, 40% alfalfa, 40% western wheatgrass; and 4) 40%winterfat, 40% alfalfa, 20% western wheatgrass. Alfalfa will provide a nitrogen source as well as fibre. Western wheatgrass has been selected as being a grass adapted to fall grazing. Harvest would occur in October samples would be used to determine biomass, nutritional quality, relative competitive abilities and component contributions to the plant community.

Meteorological data would also be collected during the period of the project.

(c3) Progress (Results)

Nov 2000 to March 2001

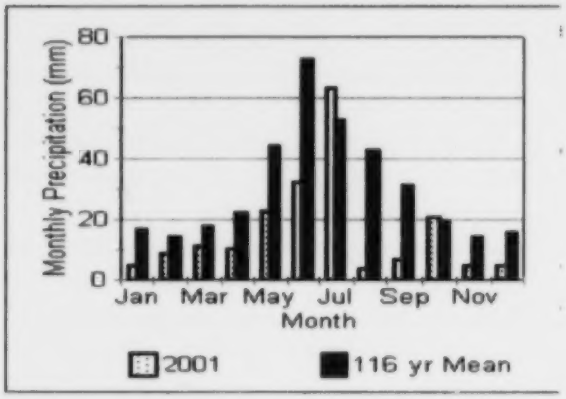
Personnel hired, and field sites selected. Due to heavy snow in early November, seeding was

delayed until spring 2001. In the meantime transplant material initiated in the greenhouse for planting in spring.

March 2001 to April 2002
c3-1 Meteorological Data:

Compared to available long term averages 2001 was drier (Figures c3-1-1 and c3-1-2). July was the only month to exceed the average precipitation. The months of January, February, March, April, August, September, November and December all receiving less than 10 mm. Evaporation for 2001 exceeded the long term average four of five months. 2001 also proved to warmer than long term averages for air and soil temperatures (Figures c3-1-3 and c3-1-4). February was the only month with below average temperatures. For 2001, May, July and October exceeded the long term average for wind with January to April being below average. For seedling establishment the environment was dry, hot and windy for 2001.

Figure c3-1-1: Monthly precipitation for 2001 and the 116 year average from the Semiarid Prairie Agricultural Research Centre meteorological facility.



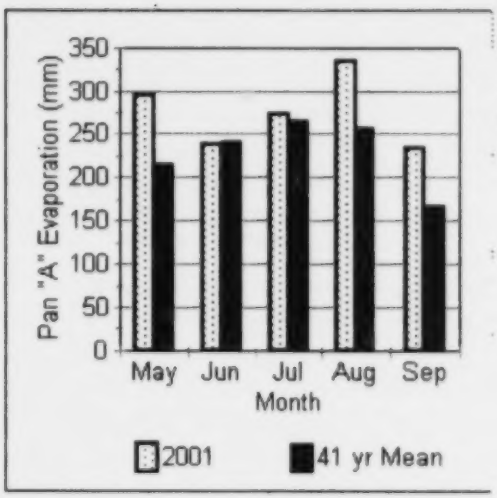


Figure c3-1-2: Pan "A" evaporation for the growing season months for 2001 and 41 year mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.

Figure c3-1-3: Mean monthly temperature for 2001 and the 116 year mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.

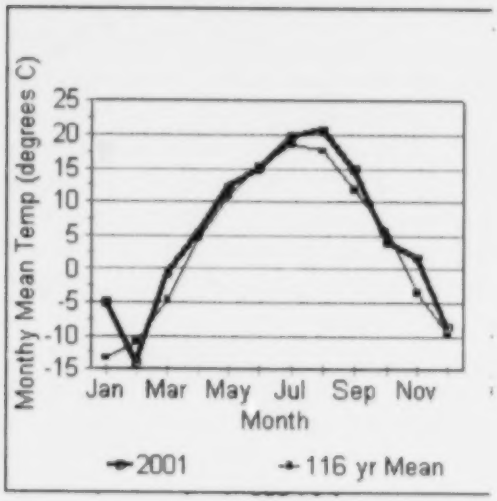


Figure c3-1-4: Monthly mean soil temperature at 10 cm depth for 2001 and 39 yr mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.

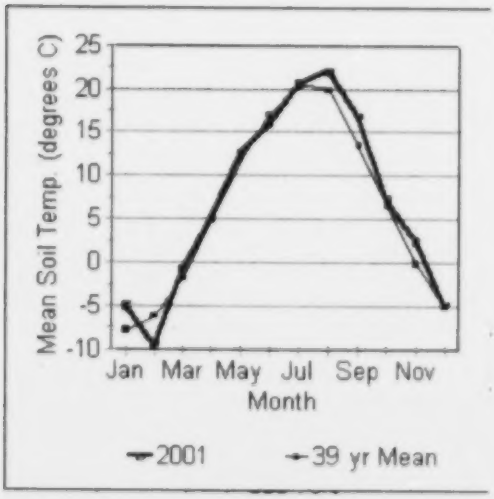
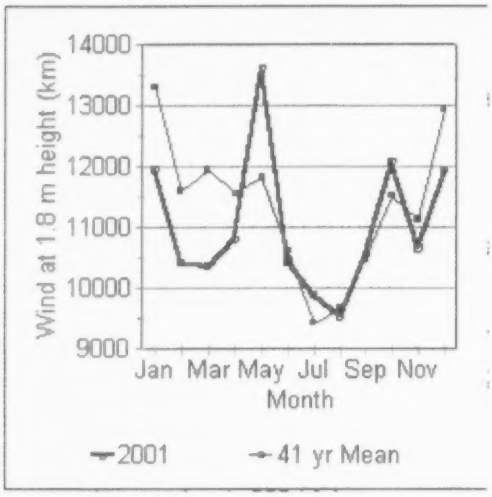


Figure c3-1-5: Wind at 1.8 m height for 2001 and 41 yr mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.



c3-2 Objective 1: Impact of fertilization and moisture

First site selected and transplants put out in weed barrier fabric 29 June 2001. Due to drought conditions the transplants were watered 3 and 9 July 2001. August water was applied on the ninth. Rep 1 of the August watering received a second watering when the September water was applied. September watering occurred on the 25th. The water applied (5.0 cm) resulted in significantly greater soil moisture (Table c3-2-1) at both dates. It would appear the moisture effect had not dissipated by the second watering date although the exact magnitude was not measurable due to an irrigating error. Retention of moisture was in part due to the weed barrier fabric creating an evaporation barrier as suggested in previous work. Readings taken on 4 September indicate a precipitation event.

Plant heights were taken 17 September and seed harvested 2 and 13 November. The results for establishment year indicate no statistically significant differences in plant height (average plant height 19.5 cm) or seed yield (average seed weight per plant per plot 0.33g). This would be expected as the treatments have not had time to have an effect.

Table c3-2-1. Soil moisture readings (% water) obtained using Time Domain Reflectometry to depth of 15 cm.

Date	1 Aug	Pr<F	21 Aug	Pr<F	4 Sept	Pr<F	14 Sept	Pr<F	27 Sept	Pr<F	11 Oct	Pr<F
Factor												
Water		0.7824		0.0011		0.0906		0.0505		0.0181		0.0143
None	23.7		15.7		19.1		19.7		15.1		16.4	
Sept	24.8		17.3		22.7		24.5		22.5		26.0	
Aug	24.2		25.3		24.3		23.5		25.0		24.6	
Fertilized		0.5762		0.5222		0.6061		0.6539		0.1382		0.4577
None	23.3		19.1		22.4		22.9		21.3		20.4	
Fall	24.9		20.6		22.9		23.2		17.6		23.9	
Spring	24.5		18.6		20.8		21.7		23.8		22.7	
CV%	11.2		15.3		16.13		13.0		22.9		20.8	

Table c3-4-1: Per cent canopy cover and species composition for 2001 three species mixes seeding averaged across replicates.

Seed Mix	Canopy Cover (%)	Winterfat (%)	Alfalfa (%)	Western Wheatgrass (%)	Weeds (%)	Bare-ground (%)
(%winterfat-%alfalfa-%western wheatgrass Grazing intensity)						
5Wf-20Alf-75WWG High	20.0	1.0	0.3	0.3	23.0	55.0
5Wf-20Alf-75WWG Low	13.8	0.8	0.5	1.0	6.0	43.8
10Wf-40Alf-50WWG High	27.5	1.0	0.8	0.3	14.0	53.8
10Wf-40Alf-50WWG Low	28.8	1.8	1.0	0.8	3.0	27.5
20Wf-40Alf-40WWG High	35.0	3.8	0.5	0.3	13.0	33.8
20Wf-40Alf-40WWG Low	16.3	2.5	0.8	0.3	5.0	30.0
40Wf-40Alf-20WWG High	35.0	5.3	0.8	0.3	42.0	52.5
40Wf-40Alf-20WWG Low	23.8	2.8	0.3	0.0	8.0	26.3

Table c3-4-2: Seedlings m^{-2} for 2001 three species mixes seeding averaged across replicates. Statistical analysis done with square root transform reported numbers have been back transformed. Numbers followed by a different letter are significantly different ($\alpha = 0.05$) for Tukey multiple range test.

Factor	Winterfat (seedlings 1/4 m^{-2})	Pr > F	Alfalfa (seedlings 1/4 m^{-2})	Pr > F	Western Wheatgrass (seedlings 1/4 m^{-2})	Pr > F
Grazing		0.9433		0.801		0.0278
High	10.3		5.3		0.5b	
Low	9.8		4.6		2.1a	
Species Mix		0.0022		0.4899		0.0531
(%winterfat-%alfalfa-%western wheatgrass)						
5Wf-20Alf-75WWG	1.5b		1		1.0ab	
10Wf-40Alf-50WWG	4.3b		9.8		3.0a	
20Wf-40Alf-40WWG	9.3b		5.5		1.3ab	
40Wf-40Alf-20WWG	25.0a		3.5		0.0b	
CV %	27.1		64.2		24.7	

c3-3 Objective 2: Impact of harvest date and fertilizer

First site selected and transplants put out in weed barrier fabric 26 to 27 June 2001. Due to drought conditions the transplants were watered 28 June, 9 July, 24 August and 3 September 2001.

For the establishment year, after the first killing frost two plants were clipped to a height of 5.0 cm to obtain an establishment year measure of production. Plants of New Mexico seed origin were significantly ($Pr > F, < 0.0001$) taller (36.0 cm vs 21.0 cm) than the DU ecovar. This resulted in significantly ($Pr > F, < 0.0001$) more production per plant for those originating in New Mexico (15.9 g vs 2.5 g).

c3-4 Objective 3: Seeding mixture

First site selected and seeded 7 June 2001. Site was given approximately 1.2 cm water using a sprinkler watering system 16 June 2001.

A large number of weeds also germinated therefore a number of control methods were attempted. Glyphosate was applied to individual weeds using a sponge. Unfortunately due to the drought conditions no control was evident. On 31 July 2001 the plots were mowed to a height of 10 cm to reduce the weed canopy. The mower was set at this height to avoid clipping any winterfat, alfalfa or western wheatgrass seedlings.

Two 1/4 m samples were harvested from each plot on 10 October 2001. No statistical differences were noted for dry matter yields for the differing mixtures. Seeded species yielded 5.6 g per m, while weeds yielded 95.6 g per m, resulting in a total dry matter yield of 100.4 g per m. (Reported numbers are averages across plots). The data indicates weeds dominated the plots but of the seeded species, winterfat appeared to establish the best under the conditions present (Tables c3-4-1 and c3-4-2). Winterfat seedling numbers increased as their per cent in the mix increased while alfalfa seedling numbers declined although amount in mix remained constant for 3 of 4 seed mixes. Western wheatgrass had the greatest numbers when it made up 50% of the seed mix. (Table c3-4-2). Although no grazing treatment was imposed in the establishment year Western wheatgrass had fewer seedlings in plots designated for higher level of harvest. This may be due to increased levels of weeds found in these plots (Table c3-4-1).

Forage quality analysis was, at the time of this writing, still underway and will be reported in the next report.

January to December 2002

c3-1-02 Meteorological Data:

Contrary to the dry year of 2001, 2002 proved to be cool and wet. Spring precipitation (April to May) was drier than the 117 yr long term mean but the rain started in June and did not stop until after September. June and August recorded monthly precipitation two times the long term average (Fig. c3-1-02-1). Potential pan "A" evaporation followed similar trends with May having high potential evaporation while June to September were well below the long term

average (Fig. c3-1-02-2). Soil and air temperatures (Fig. c3-1-02-3 and c3-1-02- 4) were below the long term averages for the growing season. The wind at a height of 1.8 m was slightly greater than the long term average (Fig. c3-1-02-5) with a peak in May. At the end of the growing season, August to December, there was less wind than the long term average.

Figure c3-1-02-1: Monthly precipitation for 2002 and the 117 year average from the Semiarid Prairie Agricultural Research Centre meteorological facility.

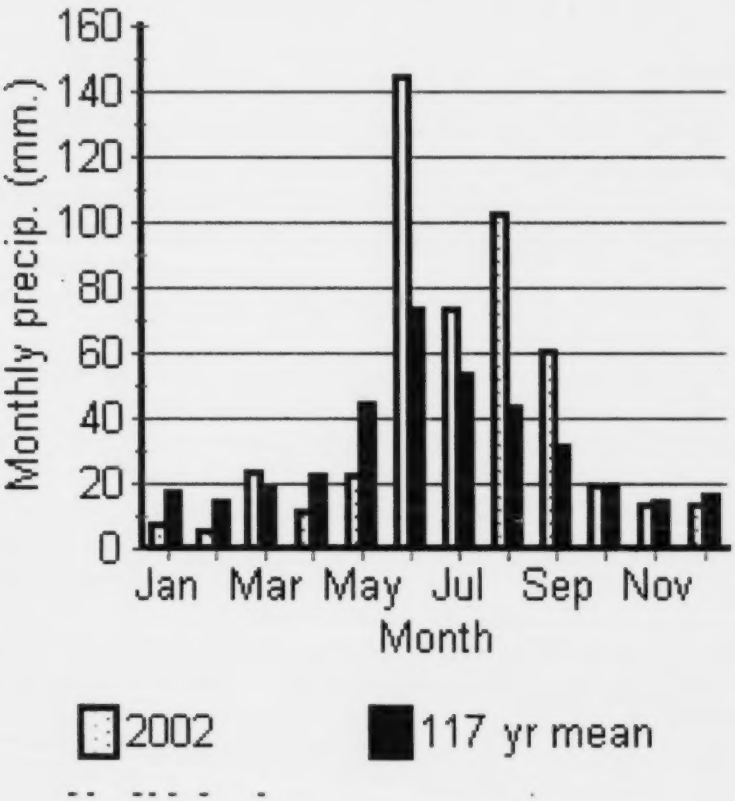


Figure c3-1-02-2: Pan "A" evaporation for the growing season months for 2002 and 42 year mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.

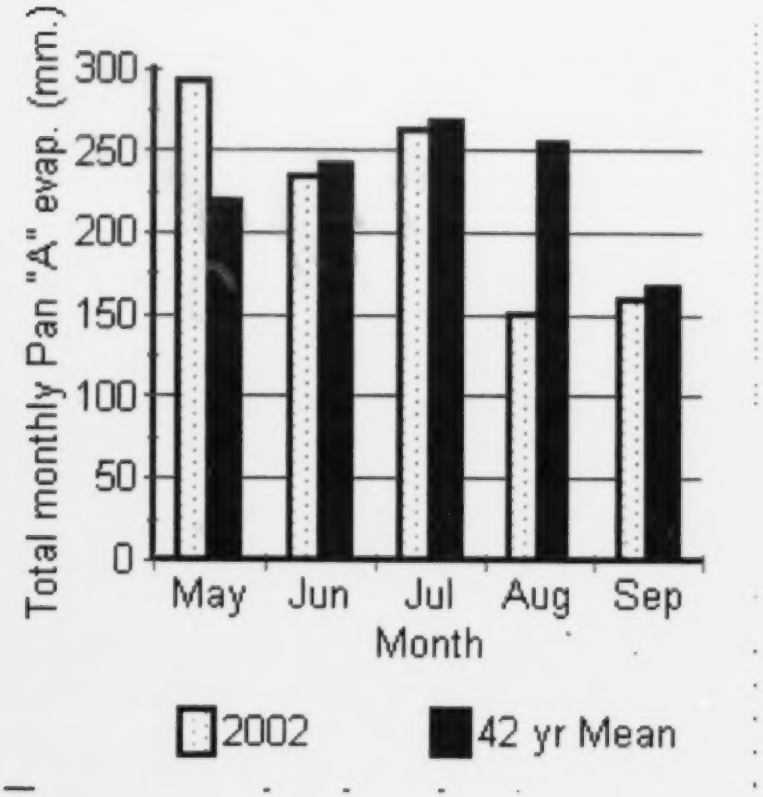


Figure c3-1-02-3: Mean monthly temperature for 2002 and the 117 year mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.

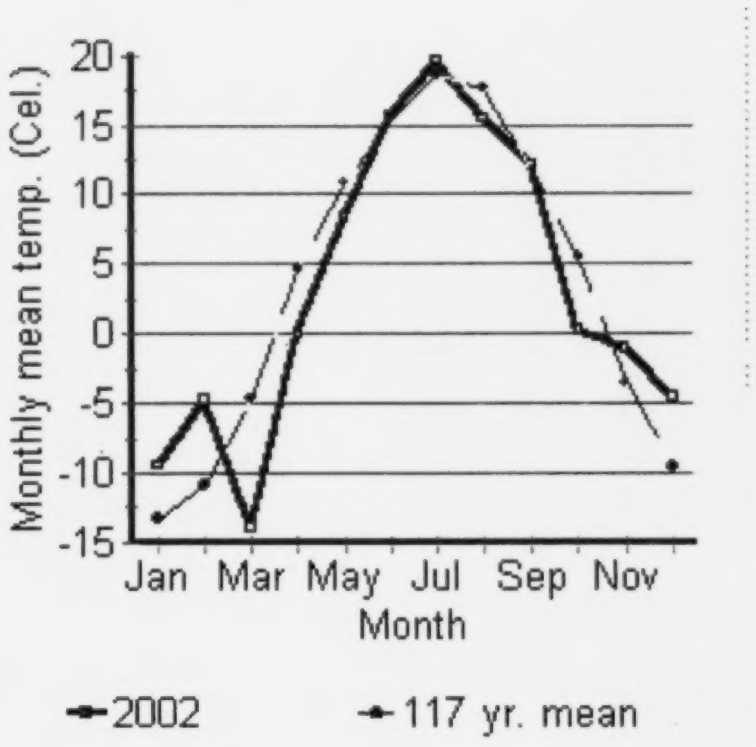


Figure c3-1-02-4: Monthly mean soil temperature at 10 cm depth for 2002 and 40 yr mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.

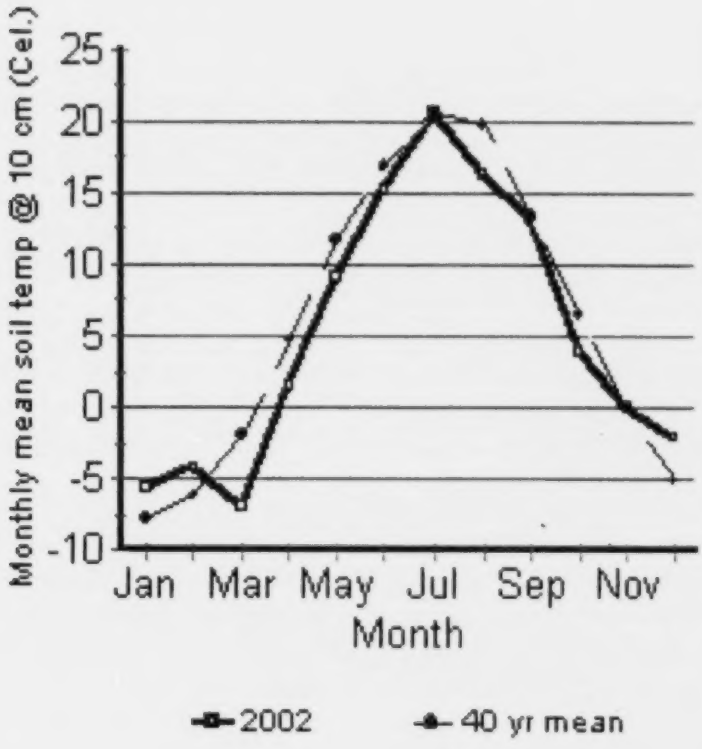
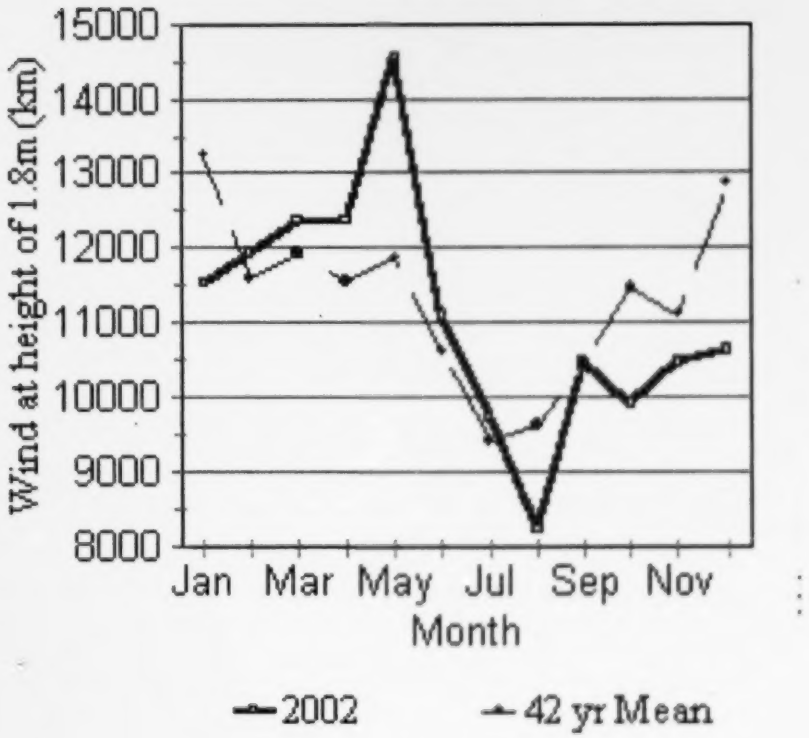


Figure c3-1-5: Wind at 1.8 m height for 2002 and 42 yr mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.



c3-2-02 Objective 1: Impact of fertilization and moisture

Site 1 (est. 2001)

The 2002 sampling season started with soil sampling to determine level of fertilization on 6 May. Fertilizer was applied 12 July. Soil moistures were determined using a time domain reflectometer on 10 May, 27 May, 25 June, 12 July, 1 August, 14 August, 29 August, 10 September and 26 September. Irrigation water was applied 7 August and 9 October. Soil temperatures were obtained 25 June, 12 July, 29 July, 14 August, 29 August, and 26 September. Plant stage of growth, plant height and canopy diameters were obtained 16 July, 19 August, and 16 September. Seed harvest occurred 20 September, 7 October and 8 October.

Plants that failed to survive the 2001-2002 winter were replaced 20 and 25 July. This will be done only for 2001-2002 winter. These plants were not included in growth or clipping measurements.

Soil water content (Fig. c3-2-02-1) further confirms a wet year was experienced at SPARC. Soil water content did not drop to levels which may have stressed the plants. Application of more water failed to provide a significant increase in water found at 0 to 15 cm.

Soil temperature measured at the base of plants also confirms a cool year (Fig. c3-2-02-2). The normally hot months of the growing season failed to have soil temperatures within the optimal range (+ 25 °) found to be required for New Mexico winterfat seedlings (Schellenberg 2003, Thygerson et al 2002). This may also explain the failure of the New Mexico winterfat plants to advance beyond the vegetative state. The temperatures were within the Ducks Unlimited ecovar™ winterfat plants optimal temperatures for seedling growth. These plants did complete their growth cycle.

Because only Ducks Unlimited ecovar™ winterfat plants completed their growth cycle statistical comparisons of growth measurements were made only for plots containing them. Additional water as well as fertilization had no effect. The lack of water effect was explained above. The lack of fertilization effect can be explained in part by the excess water leaching the ferilizer beyond the root zone before adequate uptake could occur. Branching did not occur prior to the July assessment. The July assessment found only a single primary branch with few plants having secondary branching. In August the plants developed on average 10 primary branches with 112 secondary branches. Plant heights varied with the plant measured, on average the plants obtained a height of 32 cm with a canopy diameter of 40 cm on average being reached by August. The seed yield mean was 23.1 g per plot.

Site 2 (est. 2002)

For the second establishment site soil sampling occurred 21 May and the transplants were put out 25 June. Plants which did not survive the growing season were replaced with greenhouse stock of the same age 15 August. Fertilizer was applied 24 September. Water application occurred 23 August and 9 October. First year growth assessment were done 18 October, at this time all plots had a full complement of plants. Soil moistures were obtained, using a time domain reflectometer (TDR),12 July, 29 July, 1 August, 19 August, 29 August, and 10 September. Soil surface temperatures from the base of the plants were taken 16 July, 29 July, 14 August, 29 August, and 10 September.

All plants were present as fall arrived. Additional water and fertilizer did not affect dry matter yield (11.8 g plant^{-1}), plant height (24.3 cm), canopy diameter (23.6 cm), soil moisture, or soil temperature. Soil moisture (Fig. c3-2-02-3) indicated a non-limiting water supply throughout the growing season. Soil temperature at the base of the plants indicated a cool growing season with the temperatures below optimal temperature for seedling growth (Schellenberg 2003, Thygerson et al 2002) for New Mexico sourced seed. The New Mexico plants grew as well as the Saskatchewan plants as found in the establishment year 2001. This would suggest low temperatures impact the plant growth more in the second year of growth.

Figure c3-2-02-1: Site 1 soil moisture readings (0 to 15 cm depth) for the 2002 growing season.

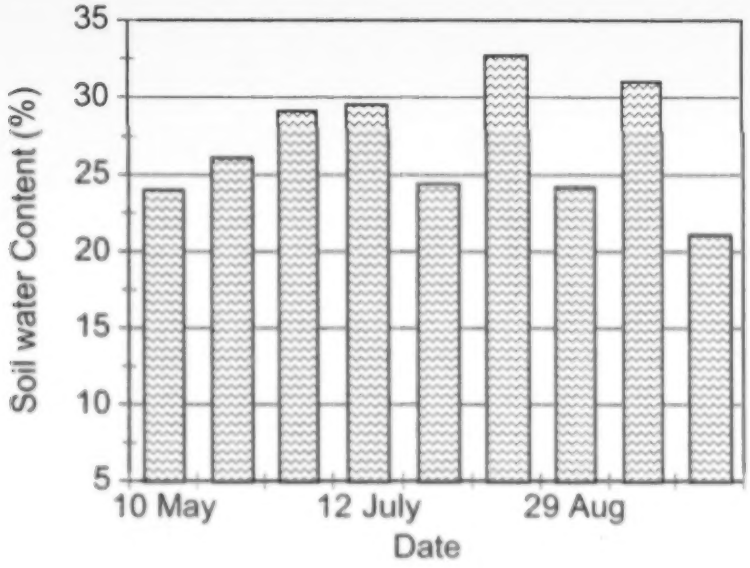


Figure c3-2-02-2: Site 1 soil temperatures from base of plants for 2002 growing season.

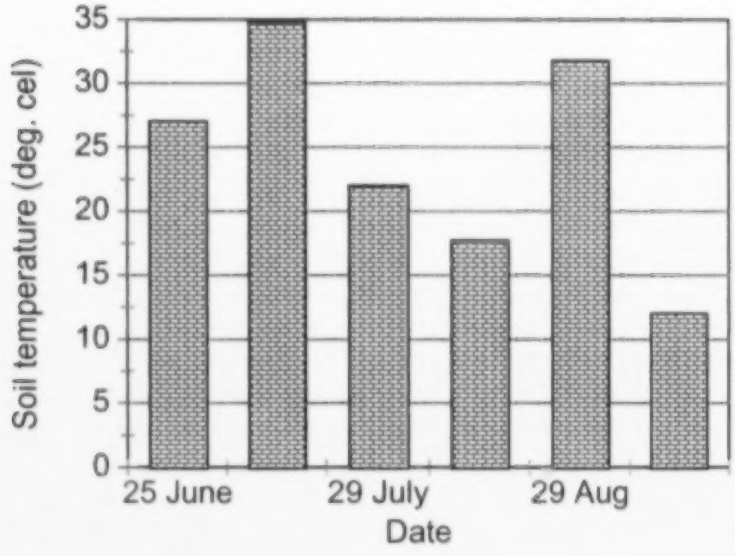


Figure c3-2-02-3: Site 2 soil moisture readings (0 to 15 cm depth) for the 2002 growing season.

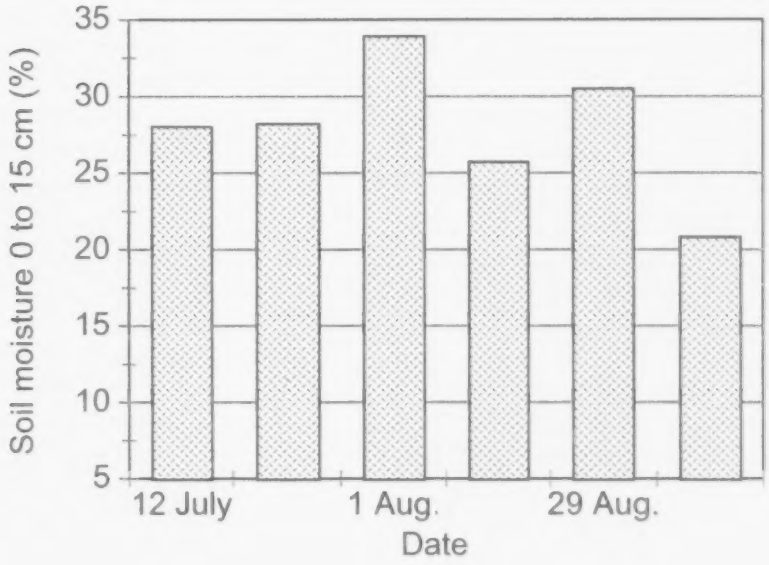
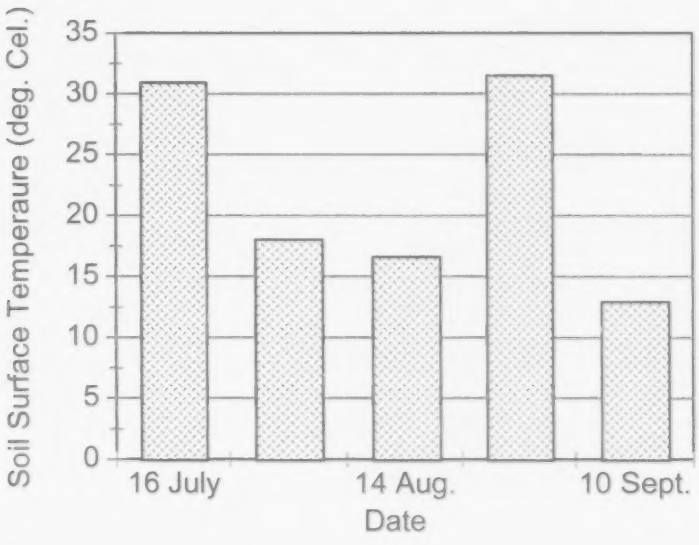


Figure c3-2-02-4: Site 2 soil temperatures from base of plants for 2002 growing season.



c3-3-02 Objective 2: Impact of harvest date and fertilizer

Site 1 (est. 2001)

Soil sampling took place 7 May to determine fertilizer requirements. Fertilizer was applied 15 July. Soil moisture was determined 10 September. Clipping treatments were done in the latter part of the months June to November. At the time of clipping stage of growth, plant height, canopy diameter, number of plants harvested, number of primary branches and secondary branches were recorded but only for those plots clipped.

Replacements for winter killed plants were put out 14 June and 17 July. These plants were not included in growth or clipping measurements.

As seen previously, soil moisture was not limiting. The 10 September soil water content was 28.6 % for the 0-15 cm depth. Fertilization had no impact on plant growth. As suggested previously the abundant precipitation may have leached the nutrients beyond the plants reach.

Date of clipping had a significant impact on measurements of growth which included: canopy diameter, plant height, branching, dry matter yield for both individual plant as well as per plot (Table c3-3-02-1). Whereas differences were only found in secondary branching, plant height and dry matter yield per plant for the two seed sources. The differences found with date of clipping are to be expected with growth progressing throughout the growing season. Growth stopped in September which coincided with killing frosts. Maximum branching was achieved by the July/August dates as was height growth. A reduction occurs in canopy diameter and height with snowfall in October. There also appears to be a loss of branches after August which may also be due to increased brittleness and damage from snowfall. A difference in growth patterns was indicated by a higher number of secondary branches for DU plants while New Mexico plants were taller and had greater individual plant biomass. Although not significant DU plants produced more biomass per plot. This was due to increased number of plants and increased branching resulting in denser plants. With denser plants there may be an increase in grazing efficiency, more material per mouthful.

Under the climatic conditions encountered DU sourced plants established in 2001 initiated growth earlier than New Mexico sourced plants. The DU plants also completed their growth cycle while New Mexico plants remained vegetative (Table c3-3-02-2) throughout the season.

What does this mean in the way of nutritionally quality? As on can see from Table c3-3-02-3 organic matter increased as the season progressed but organic matter digestibility decreased. The decrease in digestibility in part can be attributed to increased fibre as seen with the ADF and NDF analyses. Lignocellulose (ADF) made up 65% of the fibre present in the NDF. The New Mexico plants had significantly greater NDF and organic matter with greater ADF and organic matter digestibility, although not significantly different than the DU plants. Comparing Ducks Unlimited plants with New Mexico plants (Table c3-3-02-3), one notes an initially greater amount of organic matter for New Mexico but lower digestibility. The Ducks Unlimited plants declined in digestibility more than the New Mexico plants. These differences may be due in part because of the New Mexico plants inability to progress beyond the vegetative stage. Plants increase in fibre as they go to seed. This might suggest the New Mexico plants would be more nutritionally desirable if this occurs yearly. The draw back would be the New Mexico plants

inability to replace themselves.

Note: Mineral analyses are still being processed in the lab.

Site 2 (est. 2002)

Soil sampling of the site was done 27 May. Transplants were put out 4 and 5 July. Dead transplants were replaced 17 July and 15 August. Soil moisture was determined 10 September. Plant counts and plant heights were done 30 October. Two plants from each plot were clipped on 30 October.

In fall of 2002 plots contained their full complement of plants. They attained an average height of 18.3 cm. The September soil moisture reading was 30%.The Dry matter yields were significantly different for New Mexico (8.3 g) vs Ducks Unlimited plants (10.6 g). The seedlings were smaller on this dry site compared to the irrigated site. The greater growth for Ducks Unlimited plants may have been due the optimal growing temperature vs sub-optimal temperatures for New Mexico plants (Schellenberg 2003, Thygerson et al. 2002). The nutritional analyses found no differences in the ADF (20.2%) or NDF (41.3%). New Mexico plants had significantly higher organic matter (89.1%) and organic matter digestibility (72.9%) than the DU plants (86.2% OM, 66.5 % OMD). These differences between plant types are similar to the differences found with 2 year plants from site 1.

Table c3-3-02-1: Means of canopy diameter, primary branches, secondary branching, plant height, plot dry weight and plant dry weight for the factors date of clipping and seed source. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

Factor	Canopy diameter (cm)	Number of primary branches	Number of secondary branches	Plant height (cm)	Dry weight per plot (g)	Dry weight per plant (g)
Seed Source						
New Mexico	39.3	9.8	82.7 b	30.0 a	198.6	33.0 a
DU Ecovar	39.3	9.4	138.3 a	27.4 b	227.9	20.8 b
Pr > F	0.9738	0.8557	0.0006	< 0.0001	0.2041	< 0.0001
Date of clipping						
June	27.2 c	------	38.0 c	16.7 c	14.3 c	10.5 c
July	40.5 ab	10.1 a	203.1 a	39.4 b	37.0 bc	22.4 bc
August	45.1 b	11.0 a	125.7 b	34.4 a	47.6 ab	31.5 ab
September	46.0 b	9.2 ab	102.7 b	32.7 a	61.3 a	37.0 a
October	35.5 a	6.1 b	81.3 b	29.1 a	53.9 ab	33.6 ab
November	41.5 b	-----	-----	29.6 a	41.8 ab	26.2 ab
Pr > F	< 0.0001	0.0033	< 0.0001	< 0.0001	< 0.0001	< 0.0001
CV (%)	43	28	51.5	38	52	48

Table c3-3-02-2: Stage of growth as assessed on date of clipping for New Mexico and DU seed sources.

Date of clipping / Seed Source	Ducks Unlimited	New Mexico
June	Bud/flower	Vegetative
July	Flower	Vegetative
August	Flower/seed	Vegetative
September	Seed	Vegetative
October	Seed	Vegetative
November	50% seed shed	Vegetative

Table c3-3-02-3: Means of acid detergent fibre (ADF), neutral detergent fibre (NDF), organic matter (OM) and organic matter digestibility (OMD) as per cent of dry matter for site 1. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

Factor / Analyses	ADF	Pr > F	NDF	Pr > F	OM	Pr > F	OMD	Pr > F
Seed Source		0.1412		0.0003		< 0.0001		0.0721
Ducks Unlimited	34.5		52.4 b		88.1 b		62.1	
New Mexico	35.4		54.8 a		90.5 a		64.0	
Date of Clipping		< 0.0001		< 0.0001		< 0.0001		< 0.0001
June	31.2 c		48.0 d		89.3 ab		69.9 a	
July	33.7 bc		52.0 c		85.8 c		69.0 a	
August	33.9 b		54.9 abc		88.6 b		68.3 a	
September	34.9 b		53.6 bc		90.4 ab		60.9 b	
October	36.5 ab		55.6 ab		90.7 ab		55.5 bc	
November	38.3 a		57.4 a		91.1 a		54.8 c	
CV (%)		8.4		5.9		2.6		8.4

Table c3-3-02-4: Means of organic matter (OM) and organic matter digestibility (OMD) as per cent of dry matter for site 1 for seed source by date of clipping.

Date of Clipping/ Seed Source	Ducks Unlimited OM (%)	New Mexico OM (%)	Ducks Unlimited OMD (%)	New Mexico OMD (%)
June	88.9	89.6	72.5	67.2
July	82.7	88.9	68.4	69.6
August	87.9	89.3	69.1	67.5
September	89.3	91.5	60.7	61.2
October	89.6	91.8	52.0	59.0
November	90.4	91.9	49.8	59.7

c3-4-02 Objective 3: Seeding mixture

Site 1 (est. 2001)

Due to heavy weed growth the plots were divided into quarters and one quarter was randomly selected for hand weeding. Weeding occurred 16 July to 25 July. Light readings were taken 19 August. The plot area was swathed at a height of 30 cm and baled 20 August. The swath height was greater than seeded species height. Species compositions and canopy assessments were done using a 1/4 m^2 for weeded and non-weeded 11 September. Plants were clipped at a height 5 cm on 6 November. Due to heavy weed growth it was decided only one intensity of clipping would be used for all plots. Harvested samples were oven dried and submitted for lab analysis.

The environmental conditions were such that soil moisture was non-limiting as was established in previous two studies and the provided weather data for 2002. The availability of light at the top of the canopy did not differ between treatments with a mean of 1027.9 µmole m^{-2} s^{-1} on 19 August. At ground level a statistically significant difference was found between weeded (903.5 µmole m^{-2} s^{-1}) and non-weeded (265.6 µmole m^{-2} s^{-1}) indicated the potential of light being a limiting resource.

No differences were detected for % canopy (74%), alfalfa (16 %), flixweed (1%), Russian thistle (5%), narrow leaf goosefoot (4%), and purslane (1%) in a 1/4 m^2 for the factors of seed mixture and weeding. Weeding resulted in increased amount of winterfat, western wheatgrass, bare ground and trash (Table c3-3-4-02-1). Weeding did decrease the presence of the dominant weed kochia. Comparing % composition of seeded species with amount present in the seed mix (Table c3-4-02-2) one notes a trend of increasing and decreasing of species according to proportion in the seed mix. Winterfat and western wheatgrass have significant differences between lowest and highest seed mixes while alfalfa has no differences. Winterfat contributed a greater proportion of the composition suggesting a better ability to establish under weedy conditions as noted in 2001. The winterfat contribution was closer to the seeded amount than the other species in the mix contributed. Bazzaz (1996) notes late seral stage species have some capability to establish under low light condition that one would find in forests or abandoned fields. Winterfat is identified as being a late seral stage species.

A number of nutritional analyses were done on the harvested material. The only factor which impacted the analyses was weeding (Table c3-3-4-02-3). Plots with no weeding had greater acid detergent fibre, greater neutral detergent fibre and greater organic matter but has less digestible organic matter, and less crude protein. The amount of phosphorous increased with the amount of winterfat (Table c3-4-02-2) and increased with weeds although not significantly (Table c3-4-02-3).

Weeds made up 39% of the dry matter yield despite weeding, although this was still 36% less than the 75% of the non-weeded plots (Table c3-4-02-4). The weeds are contributing a higher amount of organic matter but the contribution consisted of greater fibre and was as a result less digestible. One should note harvest occurred when weeds, which were annuals, had completed their life cycle. Annual plants at the end of their life cycle contain larger amounts of indigestible fibre (Bazzaz 1996).

Site 2 (est. 2002)

Site was seeded on 5 June. Light readings were taken 19 August. Plots were split into quarters with one randomly selected quarter being weeded. Weeding took place 25 to 26 July. Species compositions were done 13 September. Insufficient numbers of the seeded species were present due to intensive grasshopper grazing and well as weed competition to continue this site. The major weed was round leaf mallow which had a closed canopy as a result few seedlings of any sort survived despite weeding. Weeding only served to increase access to seeded species for grasshopper grazing. Grasshopper bait was put out but had only limited effect. The site was abandoned.

Table c3-4-02-1 : Means % composition of species, bare ground and trash affected by weeding for 1/4 m^2.

	Weeded	Not weeded	Pr>F	CV (%)
Winterfat	14.3	10	0.0341	64
Western wheatgrass	17.5	11.3	0.0377	79
Kochia	32.8	8.7	< 0.0001	88
Bare ground	24.1	13.3	0.0003	73
Trash	12.3	2.8	< 0.0001	115

Table c3-4-02-2 : Means of % composition of seeded species and % phosphorous compared to % in seeded mix. Numbers in columns followed by a different letter are statistically significant (P>0.05) as determined by Tukey's test.

Winterfat % Composi-tion	Winterfat % seeded mix	Western Wheatgrass % Composition	Western Wheatgrass % seeded mix	Alfalfa % Composition	Alfalfa % seeded mix	% Phosphorous (g kg^{-1} DM)
7.6 b	5	18.5 a	75	10.9	20	1.8
8.1 b	10	17.5 ab	50	15.3	40	1.9
11.0 b	20	14.1 ab	40	19.1	40	1.9
21.9 a	40	7.5 b	20	19.4	40	2.4

Table c3-4-02-3 : Means for adf, ndf, organic matter, digestible organic matter, crude protein, and phosphorous expressed as % for weeded and non-weeded plots. Numbers in rows followed by a different letter are statistically significant (P>0.05) as determined by Tukey's test.

Analyses	Weeded	Not weeded
ADF	30.2 b	36.4 a
NDF	47.2 b	54.1
Organic matter	86.3 b	90.4 a
Digestible organic matter	55.8 a	51.2
Crude protein (g kg^{-1} DM)	125.0 a	106.0 b
Phophorous (g kg^{-1} DM)	17.0	23.3

Table c3-4-02-4 : Means of dry matter yields of seeded species, weeds and total for weeded and non-weeded plots. Numbers in rows followed by a different letter are statistically significant (P>0.05) as determined by Tukey's test.

Dry matter Yield (g m^2)	Weeded	Not weeded
Seeded species	62.8	46.4
Weeds	40.4 b	138.0 a
Total	103.2 b	184.4 a

January to December 2003

c3-1-03 Meteorological Data:

The year, 2003, was in sharp contrast to the wet year of 2002. From 21 June until 15 September only 50 mm of precipitation was received making 2003 the 3rd lowest total in 118 years (Judeisch 2004). Contributing to the drought conditions were the above normal air temperatures, the 5th warmest on record (Judesich 2004).

Contrary to last year (Figure c3-1-02-1) spring 2003 precipitation was above normal in April to normal in May and June (Figure c3-1-03-1). The precipitation stopped in July and resumed in September with snow occurring in late October and staying. In conjunction with the lack of moisture for July and August Pan "A" evaporation (Figure c3-1-03-2) was well above the 42 year average and last year's (Figure c3-1-02-2). Mean monthly temperatures contributed to the severe drought conditions with above average temperatures for the July/August period (Figure c3-1-03-3) and higher than 2002 (Figure c3-1-02-3) Above average temperatures are noted for November, December 2002 and January 2003. Soils temperatures followed a similar trend (Figures c3-1-02-4, c3-1-03-4). Wind in 2003 was below the 42 yr average for most months, except June, August and November (Figure c3-1-03-5) which resulted in increased evaporation due to higher than average winds during the hottest period.

The proceeding paints a picture of a extreme hot and dry conditions during growth and seed development period (July to August).

Figure c3-1-03-1: Monthly precipitation for 2003 and the 117 year average from the Semiarid Prairie Agricultural Research Centre meteorological facility.

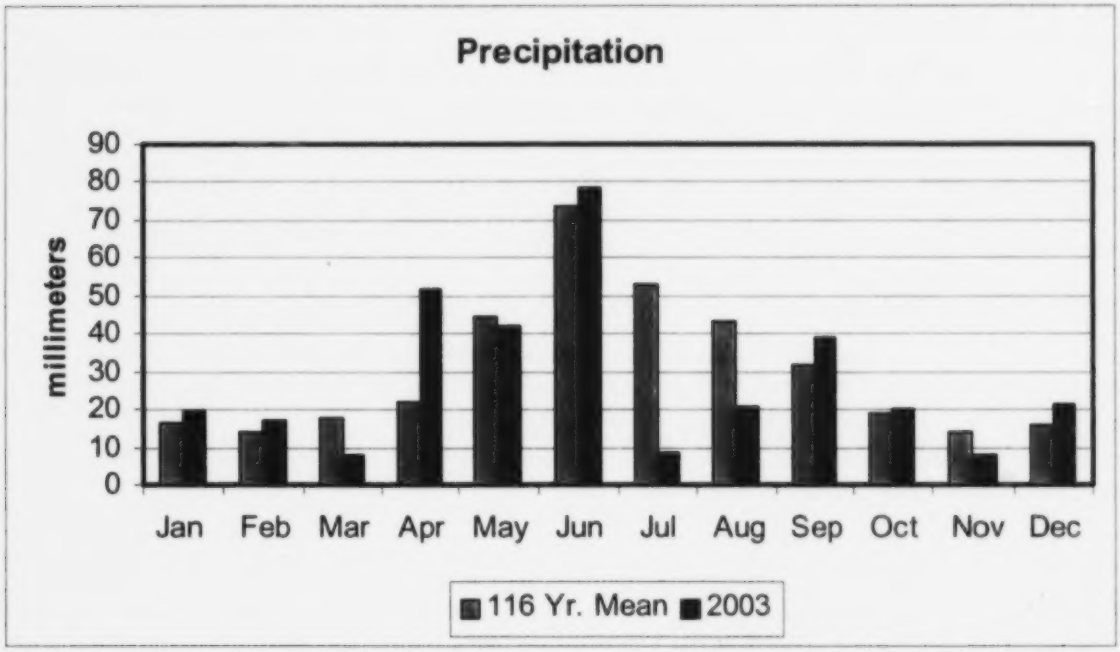


Figure c3-1-03-2: Pan "A" evaporation for the growing season months for 2003 and 42 year mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.

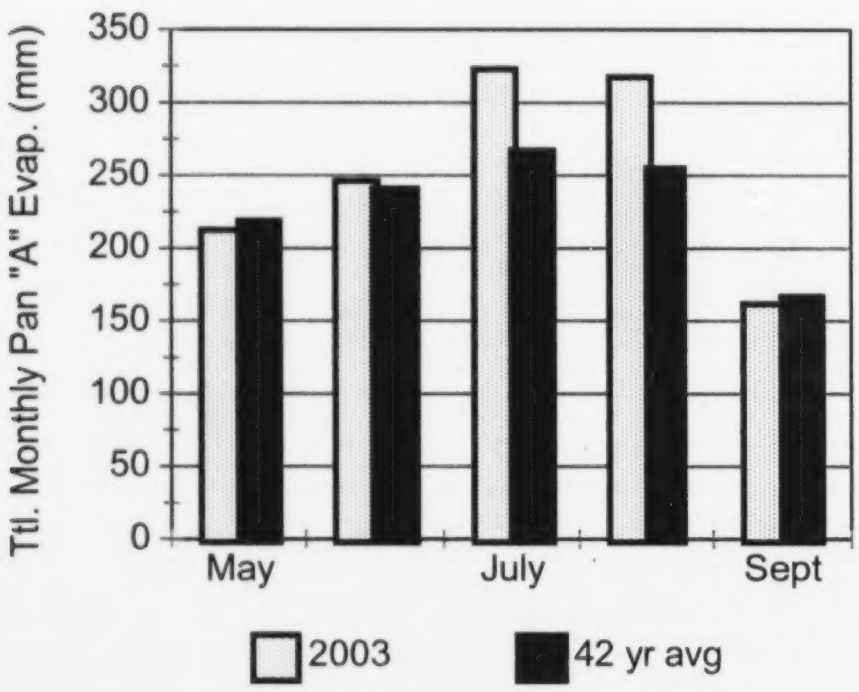


Figure c3-1-03-3: Mean monthly temperature for 2003 and the 117 year mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.

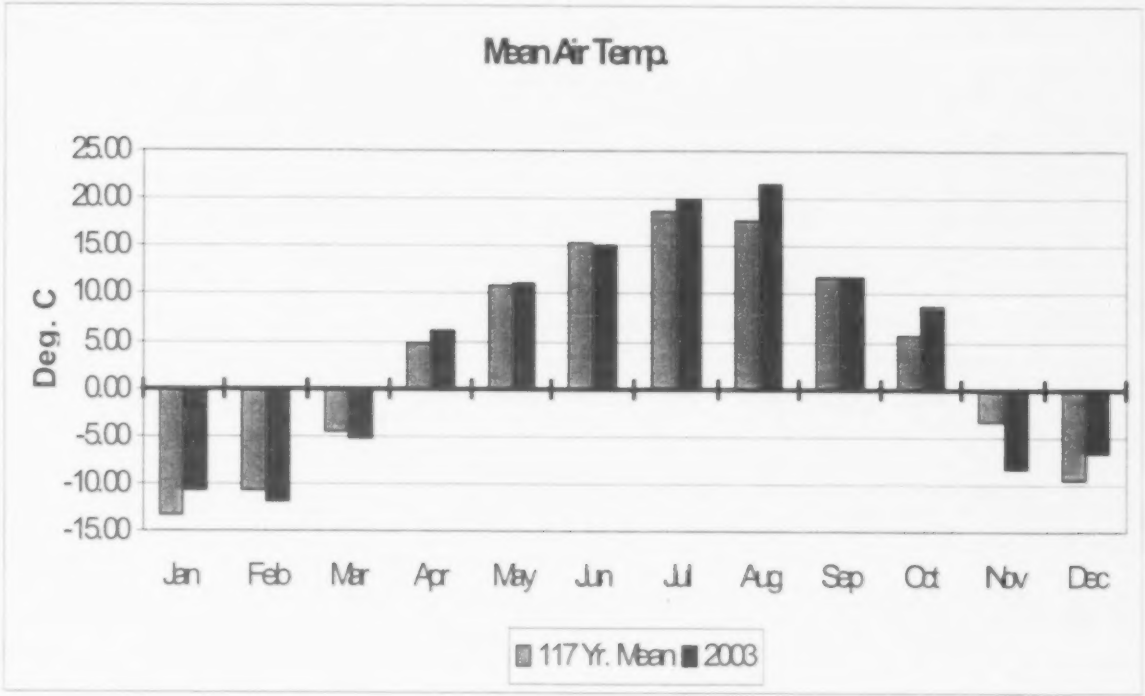


Figure c3-1-03-4: Monthly mean soil temperature at 10 cm depth for 2003 and 40 yr mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.

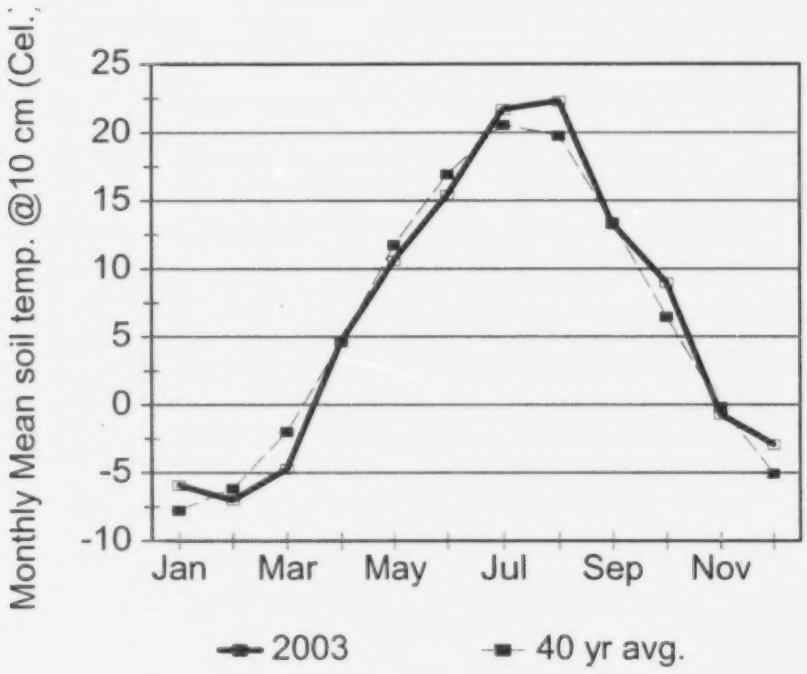
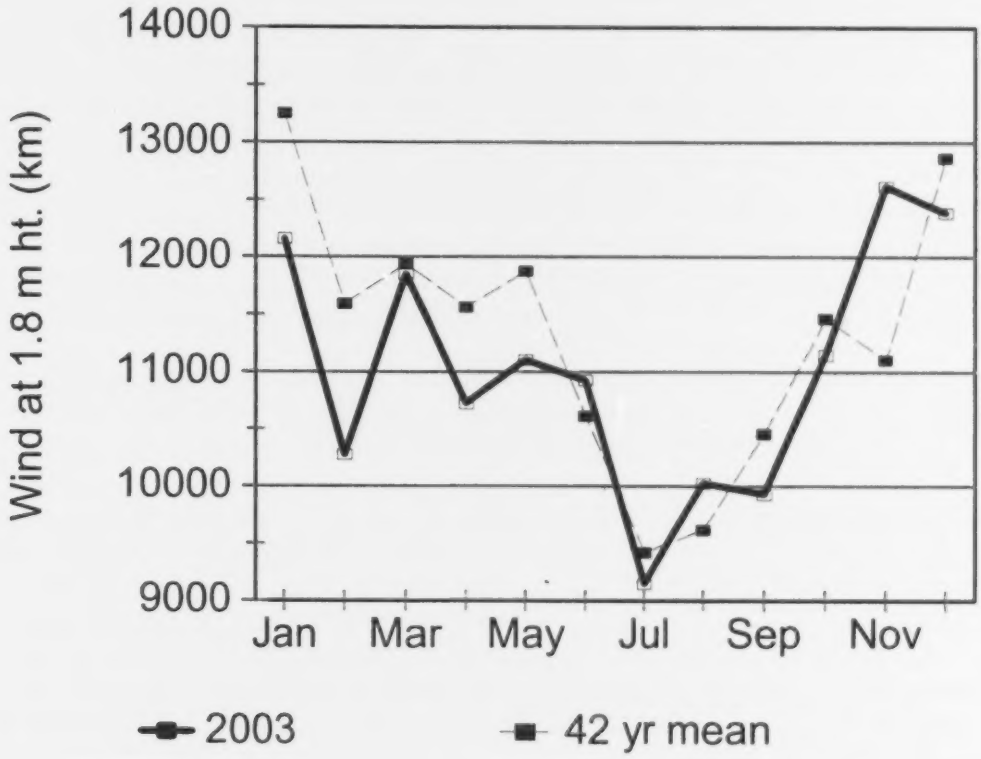


Figure c3-1-03-5: Wind at 1.8 m height for 2003 and 42 yr mean from the Semiarid Prairie Agricultural Research Centre meteorological facility.



Overall observations

Plants from the New Mexico seed source suffered a die back . Temperatures which winterfat, from Utah, can withstand during the winter are noted as -80° C (Harper et al 1990) well below temperatures recorded at Swift Current for the winter of 2003-2003 (Figure c3-1-02-4, c3-1-03-3). Hild and Morgan (1993) noted mulch will effect crown growth with a decrease in evapo-transpiration. This decrease in evapo-transpiration combined with record precipitation in 2002 (Figure cs-1-02-1) more than likely resulted in an increase in soil pathogens. Harper et al (1990) and Nelson et al (1990) concluded similar conditions resulted in a dieback of winterfat in the southwestern United States. Although not all New Mexico plants died and DU ecovar plants were relatively untouched. The survival of DU plants indicates potential disease resistance in the DU seed source.

C3-2-03 Objective 1: Impact of fertilization and moisture

Deviation: Plants were not dug up to examine root biomass. An additional of data collection will occur instead to determine longer term mineral accumulation. This additional data will be outside contract period.

Site 1 (Second year harvest)

As last year, because no New Mexico plant produced seed, the statistical analyses were restricted to DU plants.

Fertilizer was applied 7 August and 8 October prior to irrigation.

Soil moistures were obtained using a time domain reflectometer (TDR). Soil surface temperatures were obtained using a laser targeted infrared thermometer on the same day as soil moistures were obtained. The two water applications occurred on 8 August, 5 cm of water, and on 9 October, 3 cm.

Of the four dates on which soil moistures were collected, for site 1 second year of seed harvest, only the date immediately following an irrigation treatment resulted in significant differences. The mean soil moistures were as follows: 19 June 16.3%, 17 July 14.0 %, 14 August 17.5% and 8 October 19.2%. The level of moisture was higher than one would expect for bare soil with the drought conditions encountered. As Hild and Morgan (1993) noted a decrease in evaporation from the soil surface occurs when it is covered with material that creates a non-living barrier. The 14 August water treatment soil moisture was statistically significant (α=0.05) with the early irrigation being 21.2%, no irrigation 17.8% and late irrigation being 13.6%. The higher level of moisture found in blocks with no water is most likely due to drift due to a light breeze. The moisture effect was not evident from the fall 2002 application with the June readings nor were the August 2003 readings in October.

Three soil temperatures were obtained, for site 1 second year of seed harvest. No differences were detected for treatments. The temperatures were: 19 June 30.2°C, 17 July 36.7°C, and 14 August 29.9 °C. The only noted impact was a cooling effect from irrigation on 8 August, which may have contributed to slowing development (Table c3-2-03-2). The temperatures further confirm the high temperatures encountered during the summer of 2003.

Canopy and basal cover, taken 4 September, were both unaffected by fertilization or time of water application. Mean canopy cover was 75.0% of a 1/4 m^2 while mean basal cover was 50.9% of a 1/4 m^2. Mean plant height, also 4 September, was likewise unaffected by water or fertilizer application and was 41.3 cm, a 30% increase over the previous year.

Seed harvest was started 4 September and completed 1-2 October. Seed yield per plot was 45 times greater than last year and roughly equivalent to the first harvest for site 2 (Table cs-2-03-1). Although not statistically significant (α=0.05) irrigation treatments did provide an increase of 25 to 29% over no irrigation per plot and a 20% increase per plant. There was no difference in plant survival, average number of plants surviving from the original 10 was 8. Fertilizer application appears to have had a negative impact on seed production. The negative impact may be attributed to a delay in seed fill or seed set resulting in an increased number of aborted seeds. The August application did aid seed fill but for 2003 slowed development (Table c3-2-03-2). Unfortunately this also was the period of the most intense heat (figures c3-1-03-3 and c3-1-03-5) and a delay would have disrupted the processes underway.

Site 2 (First year harvest)

New Mexico plants were included in the statistical analyses for all data collected except seed production. New Mexico plants failed to produce seed.

Fertilizer was applied 7 August and 8 October prior to irrigation. Application of fertilizer failed to produce any statistically significant (α=0.05) effect on any measured factor.

Plant height, canopy and basal cover (Table c3-2-03-3) were unaffected by irrigation treatments. Ducks Unlimited plants produced more biomass as indicated by significantly more plant height, canopy and basal cover than New Mexico plants.

Soil moistures (Table c3-2-03-4) as measured by TDR were significantly higher for plots with New Mexico plants. This being a result of less utilization by fewer and smaller plants. Any irrigation effect from fall of 2002 was not evident in June. Six to seven days following irrigation with 5 cm of water (7 August and 8 October) the treated plots had significantly more soil moisture. Three weeks after the August irrigation no difference in soil moisture was detectable. As with site 1 greater soil moisture was retained for the same reasons.

Temperatures at the base of the plants (Table c3-2-03-5) were significantly lower for Ducks Unlimited plants. This was due to increased shading. The difference ranged from 3 to 5 °C. Irrigation did lower the temperature for the August reading. This lowering of the temperature may have also contributed physiological slow down.

Seed yield for Ducks Unlimited plants (Table c3-2-03-1) was not significantly affected by irrigation or fertilization as noted with the first year harvest in 2002. The seed yield was approximately 49 times greater than the first year harvest in 2002 but very similar to 2nd year harvest results in 2003, indicating a preference for seed production under a hot dry environment as opposed to a wet cool environment. Harvest took place 3, 6, and 7 October. Plots averaged 9 plants per plot. The August irrigation did result in a 23% increase in yield per plot but not a statistically significant difference. Fertilization, again not a statistical significant difference, did result in a 6 to 15% decrease in plot yields, likely for the same reasons stated for site 1 2nd year harvest. The stages of development do indicate a delayed development when irrigation was

applied (Table c3-2-03-2).

Table c3-2-03-1: Seed yields per plot and per plant for a first and second year of harvest of DU plants in 2003.Numbers followed by a different letter are significantly different (α=0.05) as determined by the Tukey's test.

Factors	First year harvest		Second year harvest	
	g			
	Per Plot	Per Plant	Per Plot	Per Plant
Irrigation				
August	1336.9	144.5	1149.0	136.6
October	1040.1	113.4	1122.4	137.1
None	1038.9	107.4	873.9	111.4
Fertilizer				
August Application	1052.2	108.4	777.6 b	101.7 b
October Application	1143.0	121.7	1135.7 a	135.0 ab
No Application	1220.7	135.2	1232.0 a	148.4 a
CV (%)	25.3	26.0	22.1	19.0

Table c3-2-03-2: Stage of growth for first and second year of harvest Ducks Unlimited plants in 2003.

	First year of harvest						Second year of harvest					
Factor	**Fertilizer**			**Irrigation**			**Fertilizer**			**Irrigation**		
	August	October	None	August	October	None	August	October	None	August	October	None
Date												
6 June	Bud/ Flower	Bud/ Flower	Bud/ Flower	Bud/ Flower	Bud/ Flower	Bud/ Flower	Bud	Bud/ Flower	Bud/ Flower	Bud/ Flower	Bud/ Flower	Bud/ Flower
16 July	Bud/ Flower/ Seed	Bud/ Flower/ Seed	Bud/ Flower / Seed	Bud/ Flower/ Seed	Bud/ Flower/ Seed	Bud/ Flower/ Seed	Flower	Bud/ Flower/ Seed	Bud/ Flower/ Seed	Bud/ Flower/ Seed	Bud/ Flower/ Seed	Bud/ Flower/ Seed
11 Aug	Flower/ Seed	Flower/ Seed	Flower / Seed	Bud/ Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed
19 Sept	Flower/ Seed	Flower/ Seed	Flower / Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed	Flower/ Seed

Table c3-2-03-3: Means of plant height, percent canopy and basal cover for first year of harvest for1/4 m^2 in 2003. Numbers followed by a different letter are significantly different (α=0.05) as determined by the Tukey's test.

Factor	Plant height (cm)	Canopy Cover (%)	Basal Cover (%)
Seed Source			
New Mexico	28.9 b	26.3 b	16.5 b
Ducks Unlimited	41.6 a	73.2 a	52.2 a
Irrigation			
August	35.6	51.3	34.4
October	34.9	45.6	37.6
None	35.3	52.3	31.1
Mean	35.3	49.7	34.6
CV (%)	29.2	42.0	58.1

Table c3-2-03-4: Mean soil moistures (%) for first year of harvest in 2003. Numbers followed by a different letter are significantly different (α=0.05) as determined by the Tukey's test.

Factor	19 June	17 July	14 Aug	8 Oct	14 Oct
Seed Source					
New Mexico	23.1 a	20.1 a	21.2 a	18.5 a	20.7 a
Ducks Unlimited	15.2 b	13.9 b	17.4 b	15.1 b	18.3 b
Irrigation					
August	19.2	17.8	24.3 a	15.9	15.9 b
October	19.2	16.9	17.3 b	16.7	26.9 a
None	19.0	16.3	16.2 b	17.8	15.7 b
Mean	19.1	17.0	19.3	16.8	19.5
CV (%)	10.2	23.6	16.4	17.8	11.1

Table c3-2-03-5: Basal temperature means (°C) for first year of harvest in 2003. Numbers followed by a different letter are significantly different (α=0.05) as determined by the Tukey's test.

Factor	19 June	17 July	14 August
Seed Source			
New Mexico	37.8 a	42.5 a	29.1 a
Ducks Unlimited	32.5 b	37.2 b	26.7 b
Irrigation			
August	34.9	39.3	26.9 b
October	34.9	40.0	29.1 a
None	35.6	40.3	27.8 ab
Mean	35.1	39.8	27.9
CV (%)	5.8	7.9	7.3

C3-3-03 Objective 2: Impact of harvest date and fertilizer

Data collection for site 1 second year of growth commenced with the first date of clipping 25 June. The additional clipping dates occurred at one month intervals: 28 and 29 July, 27-28 August, 25-26 September and 28 October. The November clip date was omitted due to snow cover which remained until spring 2004. The snowfall affected both sites. Data collection for site 2, first year of growth, commenced with clipping 17 June. As with site 1 the additional clips occurred a month apart: 18-21 July, 20-21 August, 21-22 September and 25 October.

Transplants were put out for site 2 but not site 1. Transplants were placed 24 and 27 June to replace dead or missing plants. Transplant survival was low with the intense heat and drought of 2003.

There was a strong seed source/clipping date interaction with both seed source and clipping date being statistically significant ($\alpha = 0.05$). New Mexico plant data had a higher degree of variation for all observations primarily due to decreased numbers.

Fertilizer had no statistically significant effect although there does appear to be two opposite trends: 1) the non-fertilized had greater growth for New Mexico sourced plants and 2) greater growth for fertilized DU plants. The decreased growth for New Mexico plants may be due to increased access to nutrients for pathogens or delayed development. Further research is required to determine the reason.

Despite the drought DU winterfat plants increased canopy diameter, plant height, dry matter per plot and dry matter per plant both for first year growth plants (Table c3-3-03-1) and second year growth (Table c3-3-03-2) over the previous year (Table c3-3-02-1). DU plants peaked in September for dry matter production but August for plant height and canopy diameter. Peak dry matter production was eighteen times greater than the previous year for second year growth, and fourteen times greater for first year growth. Canopy diameter increased 1.4 times for second year growth, and slightly shorter for first year growth. Plants were 10 % taller for first year growth, 20% taller for second year growth when compared with the tallest heights of 2002. For both sites plants started growth as larger plants. Clippings dates had a great impact on the amount of biomass present. The biomass decrease in fall was due to loss of seed resulting from dispersal resulting from high winds. At this point in time no impact can be seen from the harvest dates, ie no loss of plants or direct decrease in productivity. Drought affected the younger plants productivity more than plants experiencing their second year of harvest. Possible reasons include greater root development and previous year growing conditions . Earlier clipped plants had greater increases in yields than later clipped plants when comparing dry matter per plant in 2002 and 2003. The September clip had a 66% increase while the June clip had a 85% increase which agrees with observations made by Romo et al (1995).

The New Mexico plants had decreased across all measurements of biomass when compared to yields from the previous year. Their biomass production did not peak but continued into fall. When one examines the number of plants surviving in the second year of growth, plants harvested in spring survived in significantly ($\alpha=0.05$) greater numbers than fall clipped plants. Continued growth indicates no fall dormancy setting in by October, potentially leaving the plants to be affected by onset of winter temperatures

Number of branches for first year and second year harvest was significantly greater

(α=0.05) for DU plants (Table c3-3-03-3). Primary branches did not change over the growing season. Secondary branching did increase significantly (α=0.05) until August and then declined. Branch diameters of plants in second year of harvest were significantly different between seed sources (α=0.05). For both, diameter continued to increase until the final clip. The increase was significantly different between June to August period and September to October. New Mexico plants had thicker branches.

As in previous years only DU plants completed the full growth cycle (Table c3-3-03-5). Maturity rate was similar to 2002 (Table c3-3-02-2). New Mexico plants did progress to the bud stage. Fertilizing had no detectable affect.

Seventeen minerals are required by beef cattle (NRC 1996) but are often not examined in forage. They are divided into two groups macrominerals (calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), chlorine and sulfur (S)) and microminerals (chromium, cobalt (Co), copper (Cu), iodine, iron (Fe), manganese (Mn), molybdenum (Mo), nickle, selenium (Se), and zinc (Zn)). The aforementioned minerals plus cadmium (Cd), and boron (B) were examined. Cd and B were selected because of suggested concentrations in the southwest area of Saskatchewan. Also for the purposes of this discussion N was included as crude protein.

For 2002 new plants (Table c3-3-03-7) with only a small fall sampling the following minerals were statistically not significantly (α=0.05) different: Mg, Cu, and Se; the rest were. Indicating a significantly different ability to access and concentrate mineral resources. For an Angus replacement heifer in the first trimester (see Table c3-3-03-6) Zn, Cu, Co, Se would be deficient for DU plants while Cu, and Co were deficient for New Mexico plants. Minerals which were at or over the maximum tolerance for the aforementioned animal were: S and Mg for both, and Fe for DU plants.

For 2002 plants with two years of growth and first year of harvest only, Co and Na (Tables c3-3-03-8 and c3-3-03-9) accumulation were not significantly different (α=0.05) for seed source. Fertilizer decreased the amount of Ca. With an added year of growth, dilution due to increased woody material has occurred. Co peaks when the plant flowers, as does Fe while Na increases until seed set (Table c3-3-03-8). For an Angus replacement heifer in the first trimester fall grazing of the plants will result in adequate Ca, Na, and Fe but insufficient Se, Cu and Co. Cd levels are below the toxic level for DU plants but are at the maximum tolerable level for New Mexico. (Table c3-3-03-8) Boron and molybdenum were below toxic levels. Molybdenum was below measurable amounts (<0.5 mg kg^{-1} DM) for all samples analyzed for 2002 and 2003.

In Table c3-3-03-9 we see crude protein, K, S and Mn are adequate for fall grazing by an Angus replacement heifer in the first trimester for both plant types but New Mexico plants are significantly higher for all except Mn for which DU plants are. For Zn and P, New Mexico plants are adequate but the DU plants are deficient. New Mexico plants were higher due to the failure to mature. Plants will decrease in these minerals as they mature. Although shrubs decrease at a slower rate than many grasses or forbs. Mn shows the opposite trend for DU plants, indicating accumulation as the growing season progresses but New Mexico plants did not mature and therefore uptake was decreased.

New Mexico plants accumulated more Cd, Se, Zn, K and P while DU plants accumulated more Ca, Cu, Mn, Fe, and Co in the first year of growth. For the second year of growth Se

accumulated more in DU plants whereas New Mexico plants accumulated more Cu, and S. The other minerals remained the same as the first year. Crude protein in New Mexico plants was higher for both years of development.

Mineral analyses for 2003 again shows the two seed sources accumulating minerals differently (Table c3-3-03-10). Most trends for 2003 were as found in 2002 (Tables c3-3-03-7 to c3-3-03-9) with the following exceptions: 1) Na is reversed for plants experiencing the first year of harvest with no differences for plants in 2nd year of harvest, 2) S finds no difference for both 1st and 2nd year of harvest, and 3) Cu concentrations are now significantly different. Most mineral concentrations dropped from 2002 to 2003 but the following were exceptions: B, Mn, Co and Se. Cobalt and selenium doubled in concentration but remained well below the maximum tolerable. Magnesium continued to be present in concentrations twice the maximum tolerable. The decrease in concentrations may be due to increased growth experienced. The concentrations which increased would suggest accumulation over time although Co and Mn had similar concentrations for both 1st and 2nd year harvested plants. This would suggest a climate effect. Boron and molybdenum analyses were run only for the DU plant samples due to insufficient sample being available for the New Mexico plants.

Minerals that did not have a significant statical interaction between seed source and date of clipping remained constant between 2002 and 2003 as well as plants clipped for the 1st and 2nd year of harvest. In 2002, Fe and Na (Table c3-3-03-8) belonged to this group but not in 2003. In 2003, Mn was included only for the 1st year harvest plants (Table c3-3-03-11) . For these aforementioned minerals the inclusion/exclusion would appear to be associated with a climate effect. Calcium, Se, Mn, and Cd accumulated as the growing season progressed in 2003 with Se peaking when the plants were in full flower. Copper and Co remained constant for the 1st year harvest plants. For plants experiencing the 2nd year of harvest (Table c3-3-03-12) similar trends are noted for Ca and Cu. Selenium decreased during the growing season, an opposite trend as seen with 1st year harvest plants for 2003 but still had an increase between years. Further data collection over additional years will be required to determine if Se continues to accumulate or levels off. Cobalt for both years and both 1st and 2nd year of harvest shows a decrease during flowering and seed production with a rebound once the reproductive cycle is complete.

Minerals with a significant seed source/date of clipping interaction are found in Table c3-3-03-13 for 1st year harvest plants and Table c3-3-03-14 for second year harvest plants. Both seed sources showed similar trends except for Zn. For the 1st year of harvest plants in 2002 DU plants Zn declined (Table c3-3-03-9) while NM plants remained constant. In 2003 the 1st year plants for DU and NM had opposite trends while 2nd year harvest plants had the same trend. For P, K, Zn and S there was a noted decline as the season progressed for all plant types, although NM plants declined at a slower rate due to failure to progress through the reproductive cycle. For Na and Fe, accumulation occurs over the season. For DU plants and 1st year harvest of NM plants this also occurs for Mg. Iron accumulates in the older plants.

The addition of fertilizer decreased the concentration of Cu, Co, B, and Cd while increasing Na for both DU and NM plants. With fertilizer Fe increased in DU plants and increased S in NM plants (Tables c3-3-03-12 and c3-3-03-15). The impact of fertilizer had a mixed impact on mineral content and only for plants experiencing the 2nd harvest year, again indicating a delayed impact of fertilizer.

Crude protein, Mn, K, and S for both 1st and 2nd year of harvest and DU and NM plants in 2003 fall period (Tables c3-3-03-11 to 14),met the nutritional requirements of a replacement Angus heifer in the first trimester. Plants experiencing only their 1st year of harvest also met the requirements for P. New Mexico plants met the Fe requirements. Magnesium was in excess for both DU and NM plants and Fe was in excess in DU plants. Dilution should be considered for these minerals. Another source for Ca, Cu, Co and Se for both ages of plant as well as Zn for older New Mexico plants and for both ages of DU plants should be considered to meet the nutritional needs of livestock. Boron, M, and Cd were of no concern as toxins.

New Mexico plants had significantly less fibre in 2003 than DU plants (Table c3-3-03-16). For the younger plants ADF and NDF in DU plants showed a significant increase as the season progressed but NM plants showed no significant change. This occurred because of the failure of NM plants to complete their reproductive cycle. For the older plants both DU and NM plants show an increase in fibre. Fertilizer only increased the level of NDF in DU plants in the plants with a 2nd year of growth.

Organic matter and organic matter digestibility was not different between plant types for plants with two years of growth but differed significantly for plants with three years of growth, with NM plants having greater values in both (Table c3-3-03-17). Both DU and NM plants retained good digestibility values for the fall period with the younger plants having greater digestibility. Declines were noted for OM and OMD for both plant types and ages. Fertilizer had only a significant negative impact on three year old DU plants' amount of organic matter.

Table c3-3-03-1: Means for seed sources, New Mexico (NM) and Ducks Unlimited ecovar™ (DU), of canopy diameter, plant height, dry matter (DM) per plot, dry matter (DM) per plant and number of plants for the factors date of clipping and fertilizer for the second site first year of harvest. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	Canopy Diameter (cm)		Height (cm)		DM per plot (g)		DM per plant (g)		Number of Plants per plot	
Seed Source	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM
Fertilizer	48.9 a	21.6	33.4 a	20.6	647.7	21	68.2	5.1	10	3.3
No Fertilizer	45.1 b	18.4	31.4 b	22.5	571.4	26.3	59.4	6.3	10	3.4
Date of Clipping										
June	37.1 b	5.3 c	23.5 c	8.4 d	165.7 c	0.3	17.9 c	0.2	9	1
July	46.6 a	21.6 bc	32.6 ab	25.1 ab	526.7 b	14.6	52.7 b	4.7	10	2
Aug.	49.5 a	29.9 ab	35.3 ab	28.5 a	724.0 ab	37.6	78.1 a	8.7	9	4
Sept.	53.7 a	17.0 c	36.6 a	18.9 bc	869.5 a	29.7	90.0 a	7.5	10	4
Oct.	48.6 a	20.4 bc	33.7 ab	20.8 b	761.9 ab	26.2	80.4 a	5.2	9	4
CV (%)	20.7	65.8	22.2	40.9	32.2	140.8	27.2	116.2	10	56.5

Table c3-3-03-2: Means for seed sources, New Mexico (NM) and Ducks Unlimited ecovar™ (DU), of canopy diameter, plant height, dry matter (DM) per plot, dry matter (DM) per plant and number of plants for the factors date of clipping and fertilizer for the first site second year of harvest. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	Canopy Diameter (cm)		Height (cm)		DM per plot (g)		DM per plant (g)		Number of Plants per plot	
Seed Source	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM
Fertilizer	56.4	27.8	36.1	26.7	829.1	46.5	83.8	17.2	3	2
No Fertilizer	56.1	33.6	37	28	932.2	79.1	93.6	27	3	2
Date of Clipping										
June	53.3 b	16.3 c	34.0 b	12.4 c	707.2 b	13.6 c	71.2 b	3.3 b	10	5 ab
July	53.2 b	26.0 c	37.0 ab	25.4 c	787.3 ab	49.5 b	79.7 ab	15.9 b	10	4 bc
Aug.	65.4 a	39.6 b	39.5 a	34.9 b	1018.9 ab	100.6 ab	101.9 ab	18.1 b	10	0.25
Sept.	55.6 b	29.9 c	38.5 ab	39.2 b	1104.4 a	20.2 bc	111.7 a	11.6 b	10	1 cd
Oct.	53.2 b	84.8 a	33.7 b	67.8 a	775.5 ab	169.0 a	77.6 ab	107.4 a	10	1 d
CV (%)	19.1	62.9	22.8	45	27.2	77.1	27	67.8	2.4	56.5

Table c3-3-03-3: Means for primary and secondary branching for the factors date of clipping and seed source (New Mexico (NM) and Ducks Unlimited ecovar™ (DU)) for the second site first year of harvest. First site second year of harvest means for number of primary branches are also provided. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	1st Year Harvest		2nd Year Harvest
Factor	Number of primary branches	Number of secondary branches	Number of primary branches
Seed Source			
NM	2 b	15 b	4 b
DU	5 a	57 a	5 a
Pr > F	<0.0001	<0.0001	<0.0001
Date of clipping			
June	4	29 bc	5
July	4	37 ab	5
August	4	53 a	4
September	4	44 ab	4
October	3	31 bc	4
Pr > F	0.1905	0.0002	0.0059
CV (%)	36.9	39.2	44.5

Table c3-3-03-4: Means for primary, secondary and tertiary branch diameters for the date of clipping for seed sources (New Mexico (NM) and Ducks Unlimited ecovar™ (DU) from the first site second year of harvest. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	Primary branch diameter (cm)		Secondary branch diameter (cm)		Tertiary branch diameter (cm)	
Seed Source	DU	NM	DU	NM	DU	NM
Date of Clipping						
June	5.7 b	2.7 cd	2.7 b	1.6 c	1.3 b	1.2
July	6.1 b	3.9 bc	2.8 b	1.9 b c	1.1 b	1.6
August	7.0 b	5.6 b	2.8 b	2.8 b	1.0 b	1.2
September	9.0 a	5.1 b	3.5 a	1.8 bc	1.4 a	1.0
October	9.1 a	14.3 a	3.7 a	4.6 a	1.3 b	2.0
Pr>F	<0.0001	<0.0001	<0.0001	<0.0001	0.0015	0.0379
CV (%)	26.7	39.0	23.3	37.8	32.0	42.1

Table c3-3-03-5: Stage of growth as assessed on date of clipping for New Mexico and DU seed sources for plots with 1 and 2 years of growth.

	1st Year		2nd Year	
Date of clipping / Seed Source	Ducks Unlimited	New Mexico	Ducks Unlimited	New Mexico
June	Bud	Vegetative	Bud/Flower	Vegetative
July	Bud/Flower	Bud	Flower/Seed	Vegetative
August	Bud/flower/seed	Bud/Seed	Flower/seed	Bud/Seed
September	<50% Seed	Vegetative	<50% Seed	Bud
October	50% Seed	Vegetative	50% Seed	Bud

Table c3-3-03-6: Nutritional requirements of nutrients tested for Angus replacement heifer in first trimester.

Nutrient	Minimum requirement	Maximum tolerable
	----- g kg^{-1} DM --------	**------ g kg^{-1} DM ---------**
Crude Protein	72	
Ca	2.3	
P	1.8	
K	6	30
Mg	1.2	4
Na	0.6 - 0.8	----
S	1.5	4
	--------mg kg^{-1} DM --------	**-------mg kg^{-1} DM --------**
Mn	40	1000
Zn	30	500
Cu	10	100
Fe	50	1000
Co	0.1	10
Se	0.1	2
Mo	----	5
Cd	----	0.5
B*	----	150

* - Boron limits from Black et al (1984), other mineral minimums and maximums from NRC (1996).

Table c3-3-03-7: Crude protein and mineral content of plants with one growing season sampled in fall 2002.

Nutrient	DU Plants	New Mexico Plants	CV (%)
	g kg^{-1} DM	**g kg^{-1} DM**	
Crude Protein	141.3	186.7*	16.4
Ca	21.2*	18.1	13.5
P	2.5	3.4*	27.9
K	17.0	19.0*	15.4
Mg	9.7	9.2	13.7
Na	0.08*	0.07	19.8
S	4.1*	3.8	15.3
	mg kg^{-1} DM	**mg kg^{-1} DM**	
Mn	108.1*	96.7	17.7
Zn	26.3	40.2*	34.9
Cu	0.98	0.68	311
Fe	1141.9*	721.5	59.1
Co	0.033*	0.016	114.6
Se	0.038	0.041	56.5
Mo			
Cd	0.037	0.053*	39.7
B			

* - significantly different across the row (P>0.05).

Table c3-3-03-8: Mineral (Ca, Cu, Co, Fe, Na, Se, Cd) content of winterfat plants in their second year of growth harvested during 2002 in which no significant Seed*Date interaction occurred. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	Minerals						
	Ca	Cu	Co	Fe	Na	Se	Cd
Factors	---------- mg kg^{-1} DM ----------						
Seed							
DU	13107.7 a	0.40 b	0.023	868.6 a	48.8	0.087 a	0.028 b
New Mexico	11063.7 b	0.53 a	0.013	626.3 b	50.3	0.055 b	0.050 a
Clipping Date							
June	11755.8	0.5	0.011 b	631.7 b	42.8 b	0.081	0.032
July	12398	0.48	0.055 a	1338.0 a	40.0 b	0.069	0.041
August	12274.3	0.45	0.020 b	868.1 ab	39.2 b	0.073	0.034
September	12337	0.44	0.004 b	448.7 b	64.0 a	0.065	0.04
October	12530.9	0.46	0.013 b	555.9 b	49.6 a	0.083	0.051
November	11218.4	0.48	0.006 b	640.1 b	61.7 ab	0.055	0.035
Fertilizer							
Fertilized	11600.8 b	0.46	0.019	778.1	50.9	0.065	0.039
Non-Fertilized	12570.7 a	0.47	0.017	716.9	48.2	0.077	0.039
CV (%)	17.1	26.1	179.3	73.9	36.2	58.6	60.5

Table c3-3-03-9: Crude protein and mineral (K,P,Mg,S,Mn,Zn) content of winterfat plants in their second year of growth harvested during 2002 in which a significant Seed*Date interaction occurred and Seed source (Ducks Unlimited (DU), New Mexico (NM) was significant. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	Crude Protein		K		P		Mg		S		Mn		Zn	
Seed Source	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM
Units	---------- g kg^{-1} DM ----------										---------- mg kg^{-1} DM ----------			
Clip Date														
June	168.1 a	159.8 a	24.4 a	24.7 a	2.6 a	2.2	5.9 b	4.8	3.3 a	2.8 ab	70.6 b	89	20.0 ab	26.1
July	137.5 b	136.8 b	17.0 b	19.2 b	2.2 b	2.0	6.7 b	4.8	2.4 bc	2.1 c	123.5 a	96.5	23.6 a	25.9
Aug.	127.5 b	131.2 b	17.8 b	20.1 b	1.9 b	1.9	6.7 b	5.1	2.8 ab	2.3 bc	97.3 ab	93.1	20.4 ab	20.3
Sept.	126.9 b	143.7 ab	16.9 b	21.1 ab	1.8 b	2.3	8.3 a	5.3	3.0 ab	3.0 a	97.7 ab	94.1	19.0 bc	23.0
Oct.	99.4 c	128.2 b	13.7 c	18.9 b	1.3 c	1.9	7.1 ab	5.5	2.5 bc	2.9 a	108.0 a	82.8	16.7 bc	24.4
Nov	94.9 c	134.3 b	10.6 d	17.2 b	1.2 c	2.1	6.1 b	5.1	1.9 c	2.4 bc	104.4 a	89.2	16.0 c	26.5
CV(%)	22.1	13.4	27.4	19.4	29.7	19.2	18	18.9	24.1	21.9	26.1	17.9	19.8	26

Table c3-3-03-10: Crude protein and mineral content of plants by seed source for second (1st harvest) and third (2nd harvest) year of growth in 2003. Numbers followed by different letters in the row are significantly different (P>0.05) as determined by the Tukey's test.

	1st year of harvest			2nd year of harvest		
Nutrient	DU	NM	CV(%)	DU	NM	CV(%)
	g kg^{-1} DM					
Crude protein	131.7 b	163.8 a	12.7	110.1 b	142.1 a	19.7
Ca	15.9 a	15.0 b	11.6	13.3	13.3	12.4
P	2.0 b	2.1 a	22.8	1.5 b	1.8 a	24.8
K	16.5 b	17.7 a	14	15.8 b	19.3 a	19.9
Mg	8.3 a	7.6 b	13.8	7.1	6.5	20.7
Na	0.06 b	0.13 a	59.3	0.07	0.07	31
S	2.9	2.8	13.1	2.6	2.8	17.7
	mg kg^{-1} DM					
Mn	116.3 a	106.4 b	17.8	121.8 a	93.3 b	17.2
Zn	21.3 b	35.8 a	30.3	18.5 b	22.7 a	17.2
Cu	0.43 b	0.61 a	30.9	0.45 b	0.56 a	14.3
Fe	933.5 a	554.5 b	57.4	843.3 a	479.6 b	34
Co	0.078 b	0.099 a	47.3	0.068 a	0.051 b	31.3
Se	0.066	0.056	34.9	0.11	0.10	35.1
Cd	0.030 b	0.047 a	31.8	0.026 b	0.039 a	32.9
B	na [z]	na	na	28.8 [y]	na	10.8
Mo	na	na	na	<0.5	na	na

[z] - results not available due no sample submitted for analyses
[y] - insufficient sample available for New Mexico plants to be analyzed

Table c3-3-03-11: Mineral (Ca, Cu, Co, Se, Mn, Cd) content of winterfat plants in their second year of growth (1st harvest) harvested during 2003 in which no significant Seed*Date interaction occurred. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	Minerals					
	Ca	Cu	Co	Se	Mn	Cd
Factors	mg kg^{-1} DM					
Clipping Date						
June	13106.5 c	0.45	0.074	0.035 c	68.7 c	0.024 b
July	14913.5 bc	0.46	0.106	0.056 c	87.7 c	0.033 ab
August	16414.3 ab	0.51	0.087	0.095 a	121.4 b	0.033 ab
September	15303.5 abc	0.49	0.074	0.065 b	123.6 ab	0.040 a
October	17050.9 a	0.55	0.085	0.062 bc	138.7 a	0.044 a
CV(%)	11.6	30.9	47.3	34.9	17.8	31.9

Table c3-3-03-12: Mineral (Ca, Cu, Co, Se, B, Cd) content of winterfat plants in their third year of growth (2nd harvest) harvested during 2003 in which no significant Seed*Date interaction occurred. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	Minerals					
	Ca	Cu	Co	Se	B*	Cd
Factors	---------- mg kg^{-1} DM ----------					
Clipping Date						
June	13356.1 ab	0.53	0.068 bc	0.11	----	0.026
July	13187.4 ab	0.47	0.057 c	0.12	----	0.036
August	12377.1 b	0.49	0.053 c	0.12	30.6 a	0.034
September	13628.22 ab	0.51	0.054 c	0.09	24.9 b	0.028
October	14312.9 a	0.52	0.079 ab	0.09	31.0 a	0.033
Fertilizer						
Fertilized	13275.4	0.45 b	0.069 a	0.11	26.9 b	0.026 b
Non-fertilized	13311.2	0.57 a	0.051 b	0.11	30.8 a	0.039 a
CV(%)	12.4	14.3	31.3	35.1	10.8	32.9

* - Due to lack of sample only DU plants analysed

Table c3-3-03-13: Crude protein (CP) and mineral (P, K, Mg, Na, S, Zn, Fe) content of winterfat plants in their second year of growth (1st harvest) harvested during 2003 for seed source (Ducks Unlimited (DU), New Mexico (NM) in which a significant Seed*Date interaction occurred. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	CP		P		K		Mg		Na		S		Zn		Fe	
Seed	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM
Units	---------- g kg $^{-1}$ DM ----------												---------- mg kg $^{-1}$ DM ----------			
Clip Date																
June	185.8 a	-----	3.3 a	------	24.3 a	------	5.3 b	------	0.04 b	------	3.0 ab	-----	25.9 a	------	669.6	------
July	140.0 b	200.2 a	2.3 b	2.8 a	20.0 b	23.6 a	6.2 b	7.1 ab	0.04 b	0.07 b	2.9 ab	3.0	25.4 ab	38.2 ab	1072	457.8
Aug	134.6 b	124.4 ab	2.0 bc	1.4 ab	13.8 c	13.2 b	9.3 a	5.8 b	0.04 b	0.05 b	3.3 a	2.5	20.1 bc	28.4 ab	884.6	949.2
Sept	116.8 c	162.2 b	1.6 c	1.9 b	12.5 c	17.0 b	10.3 a	8.1 ab	0.05 b	0.03 b	2.8 b	2.6	17.4 c	27.7 b	673.6	528.4
Oct	81.6 d	167.7 ab	1.0 d	2.3 ab	12.0 c	17.6 ab	10.6 a	8.4 a	0.14 a	0.34 a	2.5 b	3.0	17.8 c	47.5 a	1368	427.7
CV (%)	7.3	17.9	18.4	30.1	8.6	20.8	12.5	16.9	27.7	65.2	12.9	12.6	17.3	29.7	54.1	58.9

Table c3-3-03-14: Crude protein (CP) and mineral (P, K, Mg, Na, S, Mn, Zn, Fe) content of winterfat plants in their third year of growth (2nd harvest) harvested during 2003 for seed source (Ducks Unlimited (DU), New Mexico (NM) in which a significant Seed*Date interaction occurred. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	CP		P		K		Mg		Na		S		Mn		Zn		Fe	
Seed	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM	DU	NM
Unit	g kg $^{-1}$ DM												mg kg $^{-1}$ DM					
Clip Date																		
June	147.5 a	199.6 a	2.1 a	2.6 a	21.8 a	25.1 a	5.4 b	6.8	0.03b	0.04b	2.5bc	3.1	101.2 c	96.7	22.9 a	27.9 ab	778.2 bc	760.4 a
July	111.9 ab	140.1 b	2.0 a	1.8 ab	17.0 ab	19.9 b	6.7 ab	6.2	0.03b	0.04b	3.4a	3.3	104.3 c	73.9	19.3 b	24.6 ab	460.2 c	258.3 c
Aug.	101.6 bc	116.9 b	1.3 b	1.4 b	13.5 b	15.9 b	7.3 a	6.3	0.03b	0.05b	2.8b	2.3	112.1 bc	100.0	17.1 b	17.0 c	522.7 bc	397.2 bc
Sept	115.0 ab	125.8 b	1.3 b	1.8 b	14.9 b	16.8 b	7.9 a	7.4	0.03b	0.03b	2.4bc	2.7	131.0 b	117.0	16.9 b	24.1 bc	818.7 bc	678.8 ab
Oct.	74.6 c	102.7 b	1.0 b	1.0 b	11.9 b	16.7 b	8.3 a	5.5	0.21a	0.35a	2.1c	2.2	160.9 a	87.4	16.3 b	18.7 bc	1637. 0a	368.6 abc
CV (%)	22.5	17.3	24.7	25.9	23.7	16.5	16.1	26.9	31	33.1	14.1	21.1	11.3	26.2	12	20.1	27.5	45.7

Table c3-3-03-15: Mineral (Fe, Na, S) content of winterfat plants in their third year of growth (2nd harvest) harvested during 2003 for seed source (Ducks Unlimited (DU), New Mexico (NM) in which a significant seed by date of clipping interaction occurred. Numbers followed by a different letter are significantly different (P>0.05) as determined by the Tukey's test.

	Fe		Na		S	
	DU	NM	DU	NM	DU	NM
	mg kg^{-1} DM					
Fertilized	957.7 a	524.5	78.2 a	86.3 a	2682.3	3114.3 a
No Fertilizer	739.9 b	434.6	56.1 b	58.2 b	2569.9	2451.7 b
CV (%)	27.5	45.7	31	33.1	14.1	21.1

Table c3-3-03-16: Acid detergent fibre (ADF), and neutral detergent fibre (NDF) for second and third year of growth harvested in 2003. Numbers followed by a different letter are significantly different (P>0.05) for the column as determined by the Tukey's test .

	2nd Year Growth				3rd Year Growth			
Factor	**ADF (%)**		**NDF (%)**		**ADF (%)**		**NDF (%)**	
Seed Source		CV(%) 5.8		CV(%) 6.1		CV(%) 7.2		CV(%) 6.5
DU	32.0 a		51.3 a		35.2 a		54.7 a	
NM	30.9 b		49.9 b		33.2 b		52.9 b	
	DU	NM	DU	NM	DU	NM	DU	NM
Clipping Date								
June	30.3 c	----	49.8 b	----	33.1 b	26.0 b	52.5 b	45.0 c
July	32.1 abc	29.4	51.4 ab	45.7	34.9 ab	35.5 a	55.4 ab	53.1 ab
August	31.4 bc	34.3	51.0 ab	54.2	36.6 a	36.0 a	56.8 a	57.8 ab
September	33.6 a	30.4	52.8 a	50.4	35.3 ab	31.3 a	55.3 ab	53.3 bc
October	32.6 ab	28.6	51.6 ab	48.9	36.0 a	36.2 a	53.6 ab	57.1 ab
Fertilizer								
Fertilized	32.4	30.1	51.9 a	50.0	35.0	32.8	54.4	52.6
Non-fertilized	31.6	31.6	50.7 b	49.7	35.3	33.6	55.1	53.1
CV (%)	4.1	9	3.4	10.5	5.3	9.3	4.6	8.1

Table c3-3-03-17: Per cent organic matter (OM), and per cent digestible organic matter (OMD) for second and third year of growth harvested in 2003. Numbers followed by a different letter are significantly different (P>0.05) for the column as determined by the Tukey's test .

	2nd Year Growth				3rd Year Growth			
Factor	**OM (%)**		**OMD (%)**		**OM (%)**		**OMD (%)**	
Seed Source		CV(%) 2.6		CV(%) 4.8		CV(%) 1.8		CV(%) 6.1
DU	86.3		64.0		88.2 b		55.1 b	
NM	89.1		64.3		91.0 a		59.4 a	
	DU	**NM**	**DU**	**NM**	**DU**	**NM**	**DU**	**NM**
Clipping Date								
June	88.3 a	----	66.7	-----	88.1 a	88.4 c	57.9 a	65.4
July	85.8 ab	90.8	64.8	67	90.2 a	91.7 ab	56.9 a	60.9
August	86.0 ab	87.9	64.0	58.9	89.8 a	91.3 ab	54.4 ab	57.4
September	87.7 a	88.3	62.2	63.8	88.7 a	90.1 bc	54.5 ab	59.7
October	83.6 b	90.2	62.2	70.7	84.2 b	92.3 a	52.0 b	56.5
Fertilizer								
Fertilized	86.6	89.0	64.4	65.1	87.5 b	91.1	54.7	60.5
Non-fertilized	85.9	89.1	63.5	63.6	88.8 a	90.9	55.6	58.0
CV (%)	2.6	2.1	4.9	4.8	1.9	1.1	5.6	6.6

c3-4-03 Objective 3: Seeding Mixture

Determination of plot composition and harvest occurred 26-29 August 2003. The presence or absence of weeds did not appear to affect the composition of the seeded species. Bare ground and trash decreased from 2002 (Table c3-4-02-1) to 2003 (Table c3-4-03-1) A similar trend was found with winterfat and non-seeded species. Alfalfa had a slight increase while western wheatgrass increased three fold (Table c3-4-03-2). The increase appears to have been at the expense of the winterfat component suggesting winterfat will require to be seeded as a larger proportion of a mix and possibly a less competitive grass chosen. Wheat grasses are known to be highly competitive. Weeding significantly decreased Kochia and flixweed. Wild tomato, witch grass, prostrate pigweed, lamb's quarters, stinkweed were no longer present while prostrate knotweed, Russian thistle, foxtail barley and buckwheat were less than 1% of the composition.

Phosphorous content (Table c3-4-03-2 and c3-4-03-3) declined from the previous year (Table c3-4-02-2) with the final amount being less than half the amount observed in 2002. The decline may be attributed to greater biomass production and therefore dilution or decline of the winterfat component. Additional years of data are required to determine the exact cause. Weeding again had the greatest impact on nutritional factors measured (Table c3-4-03-3). The seeded species had greater fibre due in part to more rapid growth to overtop the weeds. Crude protein dropped in the seeded species, again due to the requirement of more structural fibre to overtop the weeds. The weedy species followed a similar pattern, although only the neutral detergent fibre analysis yielded a significant difference when comparing weeded and non-weeded plots. The weeds had greater digestible organic matter than the seeded species but less organic matter. Crude protein was considerably less than the seeded species. Overall quality declined from the previous year, 2002 (Table c3-4-02-3). The decline can be attributed to the climatic conditions encountered in 2003. With the xeric conditions encountered by the plants, by fall much of the leaf material had senesced leaving fibrous stalks and branches.

Dry matter yields for seed species and total (weeds plus seeded species) were not statistically different although the plot with the least amount of winterfat present did have 25% more biomass (Table c3-4-03-4). The weed dry matter production was decreased with weeding and declined with lesser amounts of winterfat suggesting western wheatgrass was more competitive than winterfat. There was a 15% decrease in dry matter production for seeded species in weeded plots and a 23% increase in non-weeded plots from 2002 (Table c3-4-02-4).Weeds decreased 4 to 10 fold from 2002. Total yields decreased to a lesser extent with decreases 1.6 to 2.9 times. The decreases were greater for the weeds than the seeded species.

Temperatures at the base of plants were high as seen in Table c3-4-03-5, further confirming the extreme xeric conditions encountered in 2003. Initially temperatures were higher in plots with less winterfat. By July the opposite was true suggesting increased shading from alfalfa and winterfat. By August leaf senescence had started to occur in both, resulting in decreased shading. On 30 June soil water was 14.9% low but not at permanent wilting point.

Table c3-4-03-1 : Means % composition of species, bare ground and trash affected by weeding for 1/4 $m^{2\ for}$. Numbers in rows followed by a different letter are statistically significant (P>0.05) as determined by Tukey's test.

	Weeded	Not weeded	Pr>F	CV (%)
Winterfat	2.2	3.4	0.3345	199.4
Alfalfa	21.6	18.4	0.5411	104.9
Western wheatgrass	41.9	38.1	0.6228	70
Kochia	7.8 b	19.7 a	0.0417	162.4
Flixweed	0.3 b	2.7 a	0.0221	281.3
Bare ground	17.7 a	4.6 b	0.0003	123
Trash	6.1	9.1	0.2004	112.3

Table c3-4-03-2 : Means of % composition of seeded species and phosphorous (g kg^{-1} DM) compared to % in seeded mix. Numbers in columns followed by a different letter are statistically significant (P>0.05) as determined by Tukey's test.

Winterfat % Composition	Winter-fat % seeded mix	Western Wheatgrass % Composition	Western Wheatgrass % seeded mix	Alfalfa % Composition	Alfalfa % seeded mix	Phosphorous (g kg^{-1} DM)
0.8 b	5	55.9 a	75	16.3	20	1
2.2 ab	10	44.6 ab	50	15.6	40	1.2
2.0 ab	20	37.2 ab	40	21.6	40	1.1
6.3 a	40	22.9 b	20	26.6	40	1

Table c3-4-03-3 : Means for adf, ndf, organic matter, digestible organic matter, crude protein, and phosphorousof weed and non-weeded plots. Numbers in rows followed by a different letter are statistically significant (P>0.05) as determined by Tukey's test.

	Seeded Species			Weeds		
Analyses	**Weeded**	**Not weeded**	**CV (%)**	**Weeded**	**Not weeded**	**CV (%)**
ADF (%)	34.5 b	36.2 a	8.3	31.2	38.4	24.7
NDF (%)	54.6 b	57.2 a	9.3	50.1 b	56.1 a	16.1
Organic matter (%)	92.1	92.3	0.9	91.5	90.1	1.9
Digestible organic matter (%)	52.2	51.5	4.4	52.9	54.7	5.7
Crude protein (g kg^{-1} DM)	82.7 a	75.1 b	12.6	81.5	66.7	38.3
Phophorous (g kg^{-1} DM)	0.9	0.9	23.9	1.1	1	29

Table c3-4-03-4 : Means of dry matter yields of seeded species, weeds and total for weeded, non-weeded, and mixture for 26-29 August 2003 harvest. Numbers followed by a different letter are statistically significant (P>0.05) as determined by Tukey's test.

Factor	Seeded species	Weeds	Total
	----------Dry matter Yield (g m^2) ----------		
Weeds			
Present	59.8	3.4 b	63.3
Absent	53.4	10.9 a	63.7
Mixture			
5% winterfat/20%alfalfa/75%western wheatgrass	70.4	3.5 b	73.9
10% winterfat/40%alfalfa/50%western wheatgrass	49	4.7 ab	53.6
20% winterfat/40%alfalfa/40%western wheatgrass	53.2	8.4 ab	61.6
40% winterfat/40%alfalfa/20%western wheatgrass	53.9	10.9 a	64.9
CV (%)	64.8	159.7	55.5

Table c3-4-03-5 : Means of basal temperature for weeded, non-weeded, and mixture. Numbers followed by a different letter are statistically significant (P>0.05) as determined by Tukey's test.

Factor	June 20	July 30	August 19	August 26
	---------- Temperature °C ----------			
Weeds				
Present	31.4	37.8	41	34.6 b
Absent	31.6	38.2	41.3	36.3 a
Mixture				
5% winterfat/20%alfalfa/75%western wheatgrass	32.5 a	35.1 b	42.7	36.1
10% winterfat/40%alfalfa/50%western wheatgrass	32.2 ab	39.1 ab	41	35.9
20% winterfat/40%alfalfa/40%western wheatgrass	29.8 b	37.8 ab	41	35
40% winterfat/40%alfalfa/20%western wheatgrass	31.4 ab	39.9 a	40.2	34.6
CV (%)	5.5	8.4	6.3	5.1

Conclusions:

c3-2 Objective 1: Impact of fertilization and moisture

Effects of fertilization required a year to have a statistically significant impact. The impact was negative in a hot dry environment, likely due to delayed flowering and seed set, resulting in aborted flowers and seed. Fertilization had the greatest effect if applied immediately prior to water application. Fertilization in spring at the bud stage with or without water needs to be investigated as well as determination of the optimum amount.

Irrigation had an overall benefit when applied, although a statistically significant impact was only seen under hot dry conditions. Irrigation did cool the basal temperature which could lead to a slowing of physiological processes. This decrease in physiological activity combined with a delay in plant development due to fertilization, could further impede seed production in years when benefits could be realized from earlier flowering and seed set.

Seed production requires higher temperatures and less precipitation than experienced in 2002. Irrigation and weed barrier fabric prevented a deficit in available soil moisture in the hot dry environment of 2003. Further refinement is required for timing of irrigation. This study did not examine potential benefits of additional water or fertilizer at bud or flowering stages of winterfat growth cycle.

Seed sources were critical determinants of seed production, with only Ducks Unlimited ecovar™ seed producing seed.

C3-3 Objective 2: Impact of harvest and fertilization

New Mexico and DU plants differ in nutritional quality and growth. New Mexico plants appear more susceptible to soil born diseases under above normal moisture conditions. But they also have nutritional qualities which are desirable and have potentially greater biomass. Ducks Unlimited plants are less productive for biomass on an individual basis but are capable of greater survival rate resulting in more plants and therefore more biomass as a group. Ducks Unlimited plants have an ability to produce under drought conditions. Production appears unaffected by early harvest as long as only 50% of biomass is removed. This would appear contrary to Romo et al (1995) recommendations but Romo et al (1995) harvested greater than 90% of the plant. There is a threshold at which plants will not recover and it lies somewhere between 50% and 90% if one allows a year's rest. Further research is required to determine the exact threshold. For survival of a winterfat community, seed set will be required to replace older dying plants. This will not occur if grazed prior to seed set. How often seed set must occur to maintain a viable population of winterfat plants needs to be investigated.

Biomass production responded positively to drought and high temperatures of 2003 when compared to the cooler and wetter year of 2002. DU plants did not die back as the NM plants did following the mesic year of 2002, indicating a potential disease resistance among DU plants which could possibly be exploited for breeding purposes.

Mineral content of the shrubs was different for both these plant types. This is the first attempt at looking at mineral accumulation of plants of the same species but differing ecotypes. There exists a potential to adjust mineral content and digestibility through genetic manipulation.

Further research is required to determine what how other ecotypes accumulate minerals within their tissues. Both types of plant accumulate Na, Fe, and Se, although Se was well below toxic levels for all the three years of this study. Iron had concentrations above the maximum tolerable level for DU plants while Mg was approximately twice the tolerable level for both plant types. New Mexico plants accumulated more cadmium than DU plants. Boron and molybdenum concentrations were low and showed no signs of accumulating in the two years tested. For fall grazing crude protein, Mn, K, and S were sufficient for replacement Angus heifer in the first trimester. Calcium, Cu, Co, P, Se, and Zn will require supplementation depending on age of plant and climatic conditions. There exits the potential for different soils to have affect mineral content of winterfat differently than those soils found in the study sites. To what degree the minerals are available for animal utilization was not investigated. What is reported are concentrations of single minerals and does not take into account the full realm of possible interactions. Additional test sites and animal studies will be required to provide a more general recommendation.

Fertilizer did not contribute to the nutritional quality.

Organic matter and organic matter digestibility remained relatively high for fall with a range of 55% to 62% organic matter digestibility for DU plants while NM plants ranged from 55% to 71%.

C3-4 Objective 3: Seeding mixture

In the year when winterfat contributed a greater amount of the dry matter, crude protein and phosphorous were sufficient to meet the needs of an Angus heifer in the first trimester. With increasing competition and harsher growing conditions the winterfat component declined as did quality. Further work is required to determine amount of winterfat seed required in the seed mix to achieve the desirable composition. A seed mix of 40% was insufficient to provide an adequate amount of winterfat in the final plant mix to obtain the desired nutritional quality in a dry year. Another approach would be to select less competitive companion species than western wheatgrass and alfalfa.

References

Bazzaz, F.A. 1996. Plants in changing environments: linking physiological, population and community ecology. Cambridge University Press, Cambridge. Pp. 320.

Black, S.A., Graveland, D.N., Nicholaichuk, W., Smith, D.W., Tobin, R.S., Webber, M.D., and Bridle, T. 1984. Manual for land application of treated municipal wastewater and sludge. Environmental Protection Programs Directorate. EPS 6-EP-84-1. 216 pp.

Harper, K.T, Wagstaff, F.J., and Clary, W.P. 1990. Shrub mortality over a 54-year period in shadscale desert, west-central Utah. *In:* E.D. MacArthur, E.M. Romney, S.D. Smith, and P.T. Tueller (compilers) Proceedings of the Symposium on cheatgrass invasion, shrub die-off and other aspects of shrub biology and management, 5-7 April 1989, Las Vegas, NV. Pp. 115-118.

Hild, A.L., and Morgan, D.L. 1993. Mulch effects on crown growth of five southwestern shrub species. J. Environ. Hort. 11:41-43.

Judeisch, D. 2004. The top ten weather events of 2003 at Swift Current. SPARC Research Newsletter No. 1, January 23, 2004.

Nelson, D.L., Weber, D.J., and Garvin, S.C. 1990. The possible role of plant disease in the recent wildland shrub die-off in Utah. *In:* E.D. MacArthur, E.M. Romney, S.D. Smith, and P.T. Tueller (compilers) Proceedings of the Symposium on cheatgrass invasion, shrub die-off and other aspects of shrub biology and management, 5-7 April 1989, Las Vegas, NV. Pp. 84-90.

NRC. 1996. Nutrient requirements of beef cattle. Update 2000. National Academy Press. Washington, D.C. 232 pp.

Romo, J.T., Redmann, R.E., Kowalenko, B.L., and Nicholson, A.R. 1995. Growth of winterfat following defoliation in Northern Mixed Prairie of Saskatchewan. J. Range Manage. 48:240-245.

Schellenberg, M.P. 2003. Germination temperature response of two ecotypes of winterfat [*Kraschenninikovia lanata* (Pursh) Guldenstaedt]. CJPS 83:65-68.

Thygerson, T., Harris, J.M., Smith, B.N., Hansen, L.D. Pendleton, R.L. and Booth, D.T. 2002. Metabolic response to temperature for six populations of winterfat (*Eurotia lanata*). Thermochimica Acta 394:211-217.

Walser, R.H., Weber, D.J., McArthur, E.D., and Sanderson, S.C. 1989. Winter cold hardiness of seven wildland shrubs. *In:* Proceedings of the Symposium on Cheatgrass Invasion, Shrub Die-off and Other Aspects of Shrub Biology and Management, Las Vegas, NV, April 5-7, 1989. Pp. 115-118.

(d) Personnel - B. Hedger Ele-01 100% of time, as of 1 Feb J. Bolton, Eg-01 100% of time after first 6 months.

(e) Equipment NA

(f) Project Developed Materials Poster for 2003 Society for Range Management Annual General Meeting, Casper Wyoming (Handout provided previously). Oral presentation given for Dept. Of Animal and Poultry Science Graduate Seminar.

(g) Project Photos NA

(h) Acknowledgement Funding acknowledged Forage field day July 2002, presentations to management and on posters developed. This work forms the core of a PhD thesis from the University of Saskatchewan. It is anticipated the work contained within this final report will be a major contribution to a number of articles to be written for scientific journals and presentations in the near future. ADF funding will be acknowledged as a key funding agency in all publications.